New and Renewable Energy Development Corporation

of Andhra Pradesh Limited

Feasibility Report

Kurukutti Pumped Storage Project (1200 MW) Vizianagaram District, Andhra Pradesh

TATA CONSULTING ENGINEERS LIMITED

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Introduction

1.0 General

M/s. New and Renewable Energy Development Corporation of Andhra Pradesh (NREDCAP) Limited is the nodal agency for promotion and development of renewable energy projects in the State of Andhra Pradesh. It was incorporated in the year 1986 in the erstwhile un-divided state of Andhra Pradesh with the following objectives:

a) Generate electricity through renewable sources like wind and solar on decentralized manner
b) Conserve energy in rural areas
c) Import & adopt viable technology & machinery in the areas of Non-conventional energy sources & ensures post installation service
d) Impart training and to promote research and development in the field of Non-conventional energy sources

With the recent thrust on development of large scale renewable (Solar & Wind) projects in the state, Government of Andhra Pradesh (GoAP) is considering development of pumped-storage hydroelectric projects (PSP's) to balance Variable Renewable Power and export surplus power to other states. GoAP has given the mandate for identification and promotion of PSP's to NREDCAP Limited. In this regard, NREDCAP has floated the tender for preparation of Feasibility Report and Detailed Project Report for seven (7) PSP's in the State of Andhra Pradesh. TATA Consulting Engineers (TCE) Limited was awarded the consultancy work for preparation of Feasibility Report and Detailed Project Report for Kurukutti PSP and Karrivalasa PSP sites, located in Vizianagaram district.

The present report briefly covers the details of feasibility studies carried out for Kurukutti pumped storage project.

1.1. Type of the Project

Kurukutti Pumped Storage Project (Kurukutti PSP) is a pumped storage scheme with an installed capacity of 1200 MW. The scheme of operation considered for the project is weekly regulation to meet the demand of about 7 hours of peak power on week days (Monday to Saturday). Off-peak pumping hours are considered as 7 hours on week days, with pumping balance storage on Sundays.

1.2. Location of Project Area

It is proposed to utilize the head available between upper dam proposed across a minor nallah draining into Boduru Gedda river and lower dam proposed across Boduru Gedda river, a tributary of Suvarnamukhi river (Nagavali river basin). The upper dam is located near Chemidipatipolam village, Salur Taluka, Vizianagaram district of Andhra Pradesh state having a geographical latitude 18° 36' 52" N & longitude 83° 02' 40.4" E. The lower dam is located near Kurukutti village, Salur Taluka, Vizianagaram district of Andhra Pradesh with the geographical latitude 18° 36' 33.8" N and longitude 83° 04' 45.6" E (Refer Exhibit - 2).

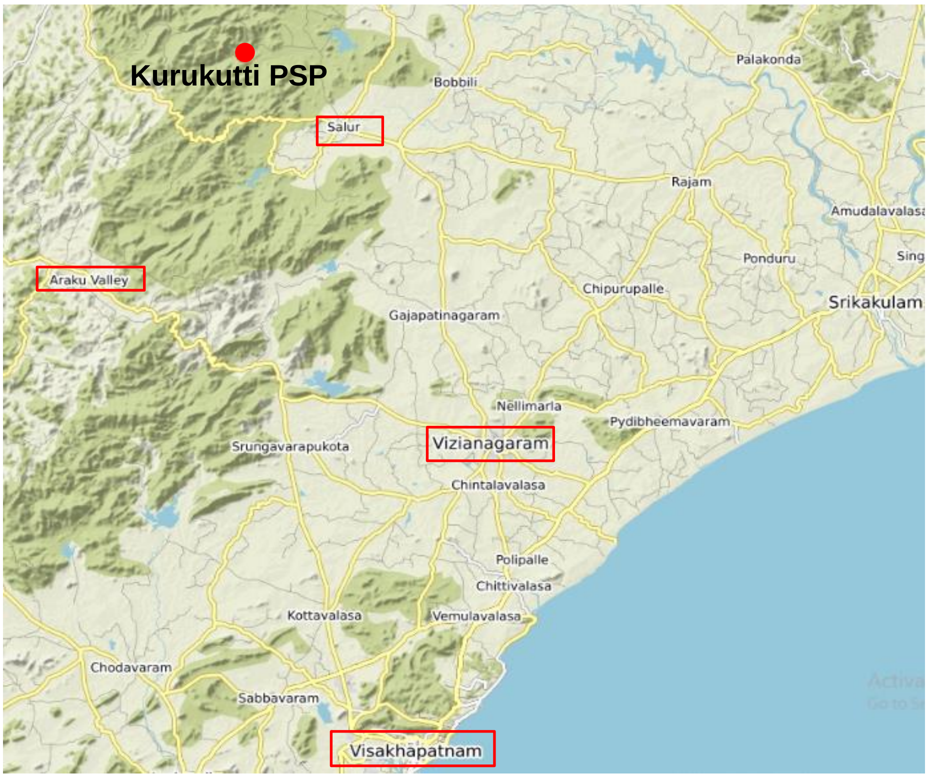


Figure - 1.1: Location Map

The National Highway (NH-26) connecting Vizianagaram with Raipur (Chhattisgarh) passes through south of the area (Vizianagaram-Salur-Koraput). All-weather metal road joins this highway south of the Salur town. Another metalled road from Tadivalasa to Ganjaibhadra passes through the project area. Besides these, there are a few fair weather roads connecting with the important villages in the interior.

1.3. Access by Air/Rail/Road/Ferry, Sea Port & Other Communication Facilities

Both upper and lower dams are accessible from Visakhapatnam and are situated about 155 km from Visakhapatnam city (via Vizianagaram & Salur towns) and about 25 km from

Salur, which is the nearest town (Refer Figure - 1.1). The nearest international airport and sea port is at Visakhapatnam which is about 140 km from the project site. The nearest railway station is at Salur, which is situated at a distance of around 25 km from the project site. The index plan and location plan of project is furnished in Exhibits - 1 & 2.

1.4. General Climatic Conditions in the Project Area

The project area falls in the Eastern Ghats section of Southern India and enjoys a tropical climate with good rains during the south west monsoon. The annual rainfall of the project area varies from a minimum of 839 mm to a maximum of 2708 m with an average annual rainfall of about 1247 mm. About 80% of total annual rainfall occurs during the monsoon months of June to October.

The temperature in the project area varies from a maximum of about 42° C during summer (March to May) to a minimum of about 9° C during winter (December to February).

1.5. General Description of Topography, Physiography and Geology of Project Area

The project area lies in the Salur region of famed Eastern Ghats in a hilly terrain. The terrain is undulating denuded hills and ridges of low to high characterizes the area. Area is drained by a number of seasonal streams from the high hills around the project locations on a steep gradient. The major part of the area is a flat, or gentles undulating country interspersed with a few hills.

Geologically, the Eastern Ghats are older and more complex than the Western Ghats and is composed of various type of rock, including khondalites, charnokites, metamorphic gneiss, granite gneiss, and quartzite. Iron ore, limestone, and bauxite can also be found in the range. In terms of its structure, the Eastern Ghats has strike-slip faults and thrusts along its ranges.

1.6. Historical background of the project

1.6.1 Earlier proposal

Australian Renewable Energy Mapping Infrastructure (AREMI) had carried out preliminary studies and identified the Kurukutti pumped storage project with a recommended energy storage potential of about 150 GWh and 18 hours storage. The proposed scheme envisaged construction of two (2) new dams/reservoirs located in Boduru Gedda river in Suvarnamukhi river basin.

1.6.2 Present Proposal

It is proposed to utilize the head available between proposed upper dam located across a minor nallah draining into Boduru Gedda river and lower dam located across Boduru Gedda river, in Suvarnamukhi river, which is a tributary of Nagavali river. Kurukutti PSP envisages a scheme to generate 1200 MW of peak power during week days by drawing water from the upper reservoir into the reversible PTG units by utilizing a gross head of about 589 m available between upper and lower reservoirs. Water will be pumped up to the upper reservoir in pumping mode during off-peak periods on week days and during extended periods on Sundays. A weekly cycle of operation of the reservoirs has been proposed for the scheme and it is found that about 11.0 Mm^3 of net storage is required for the weekly cycle. The location of upper and lower reservoirs and the schematic layout of project is shown in Figure - 1.2.

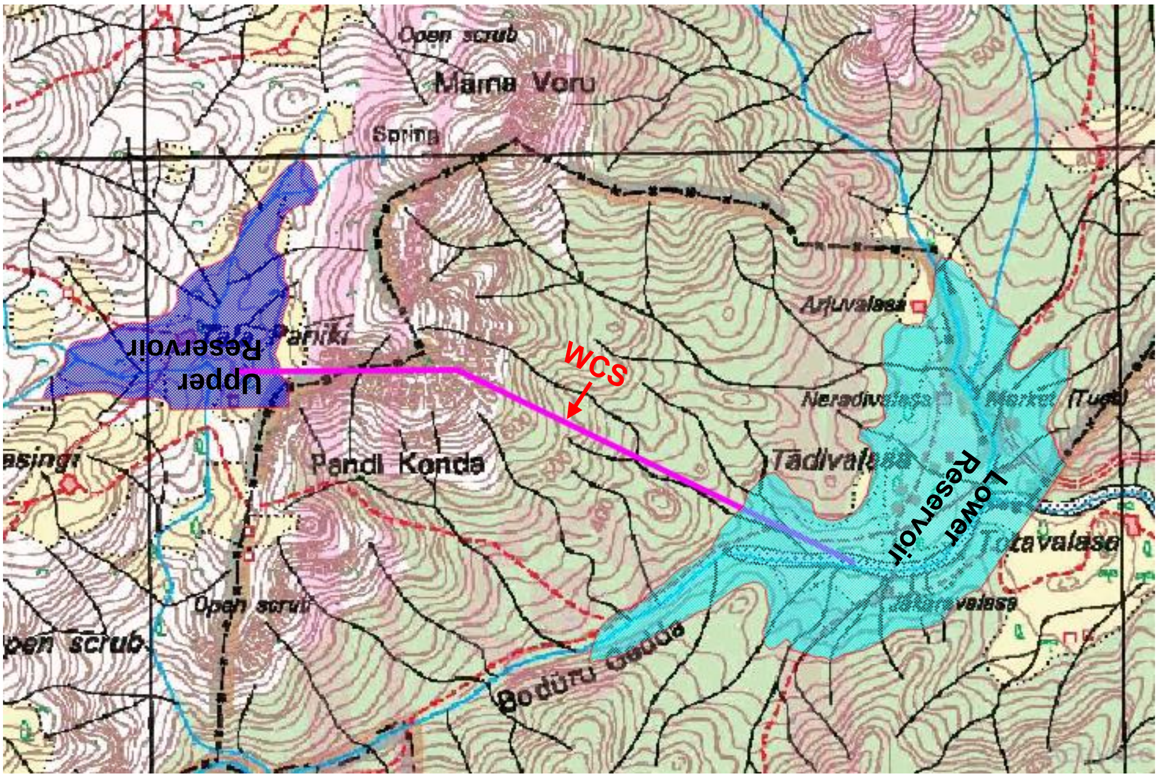


Figure - 1.2 Schematic Layout of Kurukutti PSP

In the turbine mode, a vertical intake draws water from the upper reservoir and conveys to a headrace tunnel, followed by an underground pressure shaft, which further divides into five (5) branches near the powerhouse. The five pump-turbine units are located inside the shaft type powerhouse. From the draft tubes in the powerhouse, a tailrace tunnel conveys water into the lower reservoir. In the pumping mode, water is pumped from lower reservoir through a vertical intake and let back to the upper reservoir through the same water conductor system.

1.7. Need for the Project, Possible Options and Justification for Selected Option

In line with the Government of India's (GoI's) ambitious target of installing 100 GW of solar plants by the year 2022, Government of Andhra Pradesh (GoAP) has targeted minimum solar capacity addition of 5000 MW by FY 2019-2020. GoAP has also planned to set up 4000 MW solar capacity through Solar Parks in the state of Andhra Pradesh. In addition to the above capacities, Government of Andhra Pradesh has recently decided to develop an additional solar capacity of 10,000 MW through a new corporation, viz., Andhra Pradesh Green Energy Corporation Ltd.

Generation from renewable sources (like solar, wind and NCE's) will be available partially (i.e, seasonal or intermittently in a day) and cannot be relied entirely to meet the energy/power requirements throughout the day/year. Also, this will result in grid stability issues. Hence, large-scale addition of renewables necessitates implementation of a suitable system for storing surplus energy generated during peak generation period and utilizing the same during night/off-season as per the demand scenario.

Pumped Storage hydro-electric projects are the most reliable option available in the current scenario for large-scale energy/power storage systems and accounts for nearly 95% of the global energy storage. A pumped storage project utilizes the surplus power available during off-peak period to pump up the water for storage and meets the on-peak demand by utilizing the stored water during peak demand. Along with balancing on-peak and off-peak demands, a pumped storage scheme also helps in controlling electrical network frequency and stabilizing the operation of grid. The provision of adequate capacity of pumped storage scheme in Andhra Pradesh enables to plan for required additional installed capacity from wind and solar power that enables to:

- Meeting most of the demand significantly reducing load shedding
- Avoid wastage
- Allow export of surplus power/energy &

- Plan conservation in the use of coal by suitable generation scheduling

1.8. Alternative studies carried out for various major components of the project and final choice of the project parameters

The major aspects considered for formulation of alternative layouts are as given below:

- Utilization of available head at project site to the maximum extent feasible
- Development of economical and optimized layout
- Ease of construction
- Minimal area of land acquisition to accommodate various project components
- Avoid/minimize submergence of forest land
- Avoidance of land acquisition in the state of Odisha

Considering the above aspects, five (5) alternatives have been identified for Kurukutti PSP; viz. (Alt - 1, Alt - 2, Alt – 3, Alt - 4 and Alt - 5). Alternative - 1, which is the most techno-economically viable alternative as compared to other alternatives is considered for the project.

Based on the optimization studies carried out, clustered development of Kurukutti and Karrivalasa PSP's has been recommended by adopting a common lower reservoir. The option of common lower reservoir has been found to yield a cost benefit of about Rs 400 Crores, in addition to savings in land requirement without any impact on project capacities.

1.9. Natural Resources of the State/Region

The state of Andhra Pradesh is bestowed with bountiful natural resources (coal, limestone, bauxite and a number of minor minerals), fertile land, water, fertile river basins (Godavari, Krishna & Pennar), extensive canal system and conducive agro-climatic conditions. The state is agriculturally prosperous and is known as the "Rice Bowl of India".

1.10. Socio-Economic Aspects

The project area is located in the Salur region of Eastern Ghats of southern India which has a rich fauna and flora. Agricultural products based out of Eastern Ghats are the livelihood for the local tribal population and the major crops cultivated are paddy, cereals and millets, etc. A detailed socio-economic analysis of people, structures and property likely to be impacted by the proposed project will be planned during DPR stage.

1.11. Land Required for the Project Construction

The total land required for the project components and related works has been estimated to be about 638 Acres, which includes 628 Acres of land that needs to be acquired and 10 Acres of land which needs to be taken on lease basis. In addition to the above, the extent of land involved for Right of Way (RoW) for underground works & transmission line has been estimated to be about 460 Acres. The land area apportioned to Kurukutti PSP works out to be about 433 Acres, which includes 423 Acres of land area which needs to be acquired and 10 Acres of land area which needs to be taken on lease.

1.12. Population Affected by the Project & Occupation of the People Affected

The proposed project involves construction of upper and lower reservoirs required for weekly regulation of the Kurukutti PSP. Based on preliminary studies carried out, the project will involve submergence of agricultural lands and habitations under the upper and lower reservoirs. A detailed socio-economic analysis of people, structures and property likely to be impacted by the proposed project will be planned during DPR stage.

1.13. Environmental aspects

As explained above, the project involves submergence of habitations and agricultural land and hence will involve R & R issues, which needs to be addressed before implementation of the proposed PSP. Detailed EIA studies will be carried out during DPR stage and appropriate Environmental Management Plans (EMP) will be proposed to mitigate adverse impacts on environment due to the proposed development activity.

1.14. Inter State / Inter-national aspects

All the components of the Kurukutti PSP are located within the administrative boundary of the state of Andhra Pradesh, which is a downstream riparian state. The project envisages an annual utilization of about 2.4 Mm^3 towards recuperation of evaporation and transit losses, which is very marginal and hence does not have any impact on existing water utilization within the Boduru Gedda river catchment region. Prima-facie no interstate issue on sharing of water, benefits and cost is involved.

Since, the project is at a radial distance of 85 km from the sea coast (Bay of Bengal). The project area is not falling close to any international boundaries or the coast line and hence no international aspect is involved.

1.15. Defense angle

The project area and the vicinity are quite away from any international boundaries or the coast line and hence Defense angle clearance is not involved.

1.16. Cost and benefits of the Scheme

The cost of the project is Rs. 4766 Crores at 2020-21 price level including IDC of Rs. 538 Crores.

Benefits of the Scheme

The following are the benefits of the scheme:

i. Kurukutti PSP has been designed to meet the peaking requirement during week days in the southern region grid and in particular the state of Andhra Pradesh.
ii. The energy output of the project with an installed capacity of 1200 MW has been estimated as 2527 Mu annually.
iii. The levelized cost of generation of the project has been found to be Rs 7.85/kWh considering cost of pumping @ Rs 3.00/kWh. Kurukutti pumped storage project is a technically feasible project and will be beneficial in meeting the peaking requirement of energy during evening/night in the beneficiary state i.e. Andhra Pradesh.

1.17. Construction Program

The mode of execution of the project is considered to be an engineering, procurement and construction (EPC) manner. Hence, minimum activities are planned by the owner, limiting to functions such as construction of camps, roads, O & M and other essential infrastructural services required before the major construction agencies move in.

As a preliminary estimate, a construction period of 5 years (60 months) from the date of award of civil works package has been estimated for this project.

Approach roads are to be taken up in advance for earlier start of actual excavation of underground structures. Therefore, it is planned to get approach roads completed in the interim period between the project sanction by Government and award of work for civil works through own arrangements or item rate contracts. This will enable the construction agency under civil works package to take up the construction of individual project components with approach roads ready in hand before mobilization at site.

1.18. Salient Features

Sl. No.	Description	Upper Dam	Lower Dam
1	**LOCATION**		
	a) State	Andhra Pradesh	Andhra Pradesh
	b) District	Vizianagaram	Vizianagaram
	c) Taluka / Village	Salur / Chemidipatipolam	Salur / Kurukutti
	d) Latitude	18° 36' 52" N	18° 36' 33.8" N
	e) Longitude	83° 02' 40.4" E	83° 04' 45.6" E
	f) River	Boduru Gedda River / Suvarnamukhi River	Boduru Gedda River / Suvarnamukhi River
	g) Nearest rail head	Salur	Salur
	h) Nearest airport	Visakhapatnam	Visakhapatnam
2	**HYDROLOGY**		
	a) Quantity of water required daily for 7 hours power generation	6.1 Mm^3	
	b) Maximum usable storage required for weekly cycle of Operation	11.0 Mm^3	
	c) 90% Dependable Yield at dam site(s)	22.5 Mm^3	
3	**DAMS / RESERVOIRS**	**Upper**	**Lower**
	a) MDDL	RL 861.00 m	RL 281.00 m
	b) FRL	RL 899.00 m	RL 306.00 m
	c) MWL	RL 900.80 m	RL 307.90 m
	d) Top of Dam	RL 902.00 m	RL 309.00 m
	e) Live Storage	11.7 Mm^3	29.3 Mm^3
	f) Design Flood	150 m^3/s	976 m^3/s
4	**INTAKE**	**Upper**	**Lower**
	a. Type	Vertical - 1 No.	Vertical - 1 No.
	b. Size	3.9 m wide & 8 m high	3.9 m wide; 7 m high
	c. Trashrack bays	12 Nos.	12 Nos.
5	**HEADRACE TUNNEL**		
	a. Number	1 no.	
	b. Length	1010 m	
	c. Shape	Horse Shoe	
	d. Diameter	8.0 m	
	e. Lining	Concrete	
6	**SURGE SHAFT**		

	a. Type	Restricted Orifice
	b. Height	105 m
	c. Shape	Circular
	d. Diameter	10 m
	e. Lining	Concrete
7	**PRESSURE SHAFT**	
	a. Number	1 no.
	b. Length	1800 m
	c. Shape	Circular
	d. Diameter	6.8 m
	e. Lining	Steel
8	**POWERHOUSE**	
	a. Type	Underground (Shaft Type)
	b. Installed Capacity	5 x 240 MW
	c. Size	280 m x 52 m x 108.5 m (Height above draft tube invert)
	d. C/L of Unit	RL 232.00 m
	e. Service bay level	RL 248.00 m
	POT-HEAD YARD	
	a. Type	Surface
	b. Size	70 m x 280 m
	c. Number of transformers (GT)	5 Nos.
9	**TAILRACE TUNNEL**	
	a. Number	1 no.
	b. Length	530 m
	c. Shape	Horse-Shoe
	d. Diameter	8.0 m
	e. Lining	Concrete
	f. Invert Level	RL 222.50 m at Powerhouse, RL 267.00 m at Lower intake
10	**ELECTRO-MECHANICAL EQUIPMENT**	
	Pump Turbine	
	a. Type	Vertical Reversible Francis Pump Turbine
	b. Number	5 (Fixed speed - 3 nos. & Variable speed - 2 nos)
	c. Rated Head, Generation	569 m
	Rated Head, Pumping	603 m
	d. Rated discharge	48.2 m^3/s per turbine (Generation mode)
		40.5 m^3/s per turbine (Pumping mode)
	e. Daily hours of generation	7 Hrs. (No generation on Sunday)
	f. Daily hours of pumping	1. On week days - 7 hrs
		2. On Sunday - 8.0 hrs
	g. Ratio of length of water conductor system to design head	6.2

11	**ANNUAL POWER**	
	a. Annual generation	2527 Mu
	b. Annual pumping	3308 Mu
	c. Conversion loss	23.6 %
12	**PROJECT COST** (2020-21 Price Level)	
	a. Civil & HM works	Rs. 1279 Crores
	b. Electro mechanical works	Rs. 2400 Crores
	c. Power Evacuation	Rs. 73 Crores
	d. Other Costs	Rs. 476 Crores
	e. Total cost (including FC)	**Rs. 4228 Crores**
	f. IDC	Rs. 538 Crores
	g. Total cost	**Rs. 4766 Crores**
13	**CONVERSION COST (excluding pumping cost)**	
	a. Levelized	Rs. 3.81 /kWh
14	**CONVERSION COST (including pumping cost @ Rs. 3.0/kWh)**	
	a. Levelized	Rs. 7.85 /kWh

Chapter - II

Justification of the Project from Power Supply Angle

2.1 Justification of Project from Power Supply - Demand Considerations

Central Electricity Authority (CEA), in fulfilment of its obligations under section 73(a) of Electricity Act, 2003, brings out annually the Load Generation Balance Report (LGBR) covering the anticipated energy requirement and availability in Million Units (MU) as well as peak demand and availability in Mega Watt (MW) for each State/Union Territory, Region and All India.

The summary of anticipated power supply position for Andhra Pradesh, Southern Region (covering States of Andhra Pradesh, Karnataka, Kerala, Tamilnadu, Telangana and Union Territory of Puducherry) & All India during 2020-21 are reproduced & shown in Table - 2.1.

Table - 2.1: Anticipated Power Supply Position during 2020-21

State/ Region	Peak Power (MW)				Energy (Mu)			
	Demand	Availability	Surplus/ Deficit		Demand	Availability	Surplus / Deficit	
	MW	MW	MW	%	Mu	Mu	Mu	%
Andhra Pradesh	10,900	12,074	1,174	10.8	71,841	76,865	5,024	7.0
Southern Region	57,276	54,289	-2,987	-5.2	389,962	398,373	8,412	2.2
All India	199,348	217,507	18,160	9.1	1,407,527	1,445,085	37,558	2.7

Reference: Load Generation Balance Report 2020-21, Central Electricity Authority

As seen from the above table, the peak power and energy availability for the state of Andhra Pradesh and All India is higher than the anticipated demand. On the other hand, a shortfall of about 5.2% for peak power has been anticipated for the Southern Region. It is also observed that while CEA vide its LGBR report for 2019-20 had anticipated a surplus peak power and energy availability for Andhra Pradesh, Southern Region and All India level, there was a minor shortfall (0% to 0.7%) in the actual peak power and energy demands met during 2019-20.

Further, it is to be noted that Government of India (GoI) has set an ambitious target of installing 175 GW of renewable energy capacity by the year 2022, which includes 100 GW from solar, 60 GW from wind, 10 GW from bio-power and 5 GW from small hydro-power.

Further, an installed capacity of 450 GW is targeted from renewable energy sources by 2030.

Government of Andhra Pradesh (GoAP) vide G.O Ms. No.8, dated: 12.02.2015 has issued a new solar policy - 2015 applicable for a period of 5 years targeted minimum solar capacity addition of 5000 MW by FY 2019-2020. GoAP has also targeted to set up 4000 MW solar capacity through Solar Parks in the state of Andhra Pradesh with the support of GoI. The solar parks coming up in the AP State are as given below:

a) 1500 MW Ananthapuram - I Ultra Mega Solar park
b) 1000 MW Kurnool Ultra Mega solar park
c) 1000 MW Kadapa Ultra Mega Solar Park
d) 500 MW Ananthapuram - II Ultra Mega Solar park

Out of targeted capacity of 4000 MW, 2050 MW has been commissioned so far and balance capacity will be achieved during the 4th control period (FY 2019-20 to 2023-24). In addition to the above capacities, Government of Andhra Pradesh has decided to develop an additional solar capacity of 10,000 MW through a new corporation, viz., Andhra Pradesh Green Energy Corporation Ltd.

Generation from renewable sources (like solar, wind and NCE's) will be available partially (i.e, seasonal or intermittently in a day) and cannot be relied entirely to meet the energy/power requirements throughout the day/year. Also, this will result in grid stability issues. Hence, large-scale addition of renewables necessitates implementation of a suitable system for storing surplus energy generated during peak generation period and utilizing the same during night/off-season as per the demand scenario. Pumped Storage hydro-electric projects are the most reliable option available in the current scenario for large-scale energy/power storage systems required for maintaining grid stability.

2.2 Details of Scheme for Evacuating Power for Kurukutti PSP

Power from Pumped Storage project will be evacuated to / drawn from 400kV grid substation through 400kV single circuit line on multi circuit tower. For this purpose, 400kV transmission line feeders are provided in GIS substation to connect with grid for power evacuation. Interconnection of line is considered between Kurukutti PSP & Karrivalasa PSP along with N+1 line at Karrivalasa PSP i.e., one stand-by transmission line is provided to take care of power transfer during failure of the lines. 220/400kV Maradam substation is considered as a grid station, which is approximately 40 km away from project site for evacuation / drawal of power from proposed Kurukutti PSP & Karrivalasa PSP's.

The synchronous machines will be operated as synchronous motors to pump water back from the lower reservoir to the upper reservoir. The power requirement for the pumping mode will be drawn through the same 400kV switchyard and the 400kV transmission lines by back-feeding the generator transformers. As the power requirement for the pumping mode of PSP will be drawn from the same 400kV grid station, the adequacy of the gird station capacity shall be verified. However, the selection of substation, transmission line networks, voltage and adequacy check shall be ascertained by APTRANSCO by carrying out the detailed grid studies before finalisation of project.

2.3 Available Generating Capacity in the All India/Region/State

The available generating capacity in Andhra Pradesh, Southern Region and All India from various modes of power generation is given in Table - 2.2.

Table - 2.2: Available Generating Capacity (MW) as on March 2021*

Sl. No.	State/Region	Mode of Power Generation				Total
		Thermal@	Nuclear	Hydro	RES$	
1.	Andhra Pradesh	14714.46	127.27	1673.60	8968.59	**25483.92**
2.	Southern Region	55469.99	3320.00	11774.83	44600.15	**115164.97**
3.	All India	234728.22	6780.00	46209.22	94433.79	**382151.22**

* - Installed Capacity Monthly Reports, Mar 2021, Central Electricity Authority
@ - Thermal mode of power generation includes power generation from Coal, Gas & Diesel power plants
$ - RES (Renewable Energy Sources) includes power generation from Small Hydro Power, Wind Power, Bio-mass power, Urban & Industrial Waste Power and Solar power.

As seen from Table - 2.2, the installed capacity available as on March 2021 for meeting the power demand in Andhra Pradesh State is about 25,483.92 MW. However, as per the Government of Andhra Pradesh database (as on 31.12.2020), the total installed capacity in the state is about 19,160 MW, of which renewable energy is 8,422 MW. This is about 76% higher than the anticipated demand of 10,900 MW during 2020-21. However, it is to be noted that entire installed capacity will not be available for meeting the peak demand owing to the following reasons:

- Reduced power output from hydel stations due to non-availability/reduced water availability during summer season or due to occurrence of droughts.
- Seasonal, daily and hourly fluctuations in power output from renewable energy sources like Solar and Wind power stations.

- Non-availability of power from a few thermal power stations due to scheduled and unscheduled outages and maintenance activities or due to non-availability of coal

2.4 Peak Load and Energy Requirement in Future in Andhra Pradesh

The long term forecast of peak power demand and energy requirement during the 4th Control Period (FY 2019-20 to FY 2023-24) and 5th Control Period (FY 2024-25 to FY 2028-29) for the state of Andhra Pradesh, as approved by Andhra Pradesh Electricity Regulatory Commission (APERC) is furnished in Table - 2.3.

Table - 2.3: Peak Power Demand and Energy Requirement*

Year	FY 21	FY 22	FY 23	FY 24	FY 25	FY 26	FY 27	FY 28	FY 29
Energy Requirement (Mu)	73,212	79,146	85,776	93,106	101,306	110,561	121,302	133,594	147,599
Peak Demand (MW)	12,219	13,209	14,315	15,539	16,907	18,452	20,245	22,296	24,633

** - APERC Order in the matter of Load Forecasts and Resource Plans for 4th & 5th Control Periods, April 2019.*

2.5 Projected Peak Load and Energy Requirements

The 19th Electric Power Survey (EPS) report, covering electricity demand projection of Distribution Companies, States/UT's, Regions and the all-India Electricity demand projection has been brought out by Central Electricity Authority (CEA). The report covers year-wise electricity demand projection for the years 2016-17 to 2026-27 for Discoms, States/UT's, Regions and for the country. The report also covers perspective electricity demand projection for States/UT's, Regions and for the country for the years 2031-32 and 2036-37. The projected peak load and energy requirement for the State of Andhra Pradesh (as per Seemingly Unrelated Regression Model), Southern Region and All-India level (as per Partial Adjustment Model) considering Baseline scenario is furnished in Table - 2.4.

Table - 2.4: Peak Load and Energy Requirements (as per 19th EPS Report)

Year	Peak Load (MW)			Energy Requirement (Mu)		
	Andhra Pradesh	Southern Region	All-India	Andhra Pradesh	Southern Region	All-India
2021	9,236	53,214	191,679	71,297	364,099	1,399,360
2022	9,803	55,577	201,481	76,468	383,100	1,471,500
2023	10,405	58,062	211,783	82,014	403,253	1,547,961
2024	11,025	60,657	222,346	87,801	424,508	1,628,611
2025	11,666	63,314	233,155	93,825	446,497	1,712,168
2026	12,334	66,022	244,342	100,169	469,084	1,798,104

Year	Peak Load (MW)			Energy Requirement (Mu)		
	Andhra Pradesh	Southern Region	All-India	Andhra Pradesh	Southern Region	All-India
2027	13,029	68,802	255,911	106,836	492,432	1,886,933
2028	13,751	71,657	267,866	113,830	516,576	1,978,857
2029	14,502	74,586	280,211	121,156	541,532	2,073,968
2030	15,279	77,589	292,947	128,820	567,304	2,172,304
2031	16,083	80,666	306,077	136,827	593,895	2,273,895
2032	16,957	83,817	319,794	145,594	621,306	2,378,766
2033	17,875	87,075	334,126	154,905	649,826	2,487,950
2034	18,841	90,454	349,101	164,793	679,580	2,601,973
2035	19,858	93,959	364,747	175,291	710,642	2,721,163
2036	20,928	97,592	381,093	186,438	743,075	2,845,796
2037	22,056	101,366	398,172	198,293	776,998	2,976,390

2.6 Likely Addition to Generating Capacity in Future in Andhra Pradesh

The likely capacity addition to generating capacity during 4th & 5th control period (FY 2019 to FY 2029) in Andhra Pradesh State is given in Table - 2.5.

Table - 2.5: Likely Capacity Addition in Andhra Pradesh during 4th & 5th Control Period*

Year	Project	Capacity (MW)
FY 2021-22	VTPS stage-1 Retirement	(-) 420
	VTPS stage-2 &3Retirement	(-) 420
	New thermal (80% plf) - Private Projects	737
	Hybrid (60%plf) - Private Projects	316
	Sub-Total	**213**
FY 2022-23	Polavaram (12x80MW)	480
	VTPS stage-2 &3Retirement	(-) 420
	New thermal (80% plf) - Private Projects	1105
	Hybrid (60%plf) - Private Projects	474
	Sub-Total	**1639**
FY 2023-24	Polavaram (12x80MW)	480
	New thermal (80% plf) - Private Projects	1032
	Hybrid (60%plf) - Private Projects	442
	Sub-Total	**1954**
FY 2024-25	New thermal (80% plf) - Private Projects	1105
	Hybrid (60%plf) - Private Projects	474
	Sub-Total	**1579**
FY 2025-26	New thermal (80% plf) - Private Projects	1105
	Hybrid (60%plf) - Private Projects	474
	Sirkali – Central Gen. Station	323
	Sub-Total	**1902**
FY 2026-27	New thermal (80% plf) - Private Projects	1326
	Hybrid (60%plf) - Private Projects	568
	Sub-Total	**1894**
FY 2027-28	New thermal (80% plf) - Private Projects	1768
	Hybrid (60%plf) - Private Projects	758

Year	Project	Capacity (MW)
	Sub-Total	**2526**
FY 2028-29	New thermal (80% plf) - Private Projects	2137
	Hybrid (60%plf) - Private Projects	916
	Sub-Total	**3053**
	GRAND TOTAL	**14,760**

** - Report on State Electricity Plan (FY 2019 - FY 2029), July 2018*

In addition to the above, GoAP is planning to develop 10,000 MW of solar capacity during the next 5-10 years.

2.7 Available Plant Capacities in Future

The year wise plant capacities that will be available during the period from 2021-22 to 2028-29 (4th & 5th Control periods), as approved by APERC is reproduced in Table - 2.6.

Table - 2.6: Available Plant Capacities during 4th & 5th Control Period (MW)*

Plants	FY 22	FY 23	FY 24	FY 25	FY 26	FY 27	FY 28	FY 29
APGENCO Thermal	4,957	4,574	4,574	4,574	4,574	4,574	4,574	4,574
APGENCO Hydel	1,898	2,413	2,723	2,730	2,730	2,730	2,730	2,730
CGS	2,686	2,686	2,686	2,686	2,686	2,686	2,686	2,686
APGPCL/DISCOM Gas	792	792	792	792	792	792	792	792
IPPs – Others	222	217	217	217	217	217	217	217
NCE – Solar	5,596	5,596	5,596	5,596	5,596	5,596	5,596	5,596
NCE - Wind Power	4,740	4,679	4,615	4,615	4,611	4,601	4,599	4,599
NCE - Mini Hydel	51	46	43	40	37	30	30	28
NCE -Others	189	165	131	113	100	79	78	78
Total	**21,131**	**21,167**	**21,377**	**21,362**	**21,341**	**21,303**	**21,301**	**21,299**

** - APERC Order in the matter of Load Forecasts & Resource Plans for the 4th & 5th Control Periods, Apr 2019.*

In addition to the above approved capacities, an additional solar capacity of 10,000 MW is being planned by the Government of Andhra Pradesh. Thus, the total capacity by FY 2029 works out to be about 31,299 MW, comprising about 20,301 MW from renewable energy sources.

2.8 On-Peak and Off-Peak periods

Hourly load/demand variation for the state of Andhra Pradesh during the period from 1st April 2020 to 28th February 2021 has been obtained from Andhra Pradesh State Load Dispatch Centre (APSLDC). The hourly variation of load curve on a typical day during the three seasons viz., summer, monsoon and winter for the state of Andhra Pradesh has been plotted along with the average demand (indicated by a red dotted line) during the respective day and shown in Figures - 2.1 to 2.3.

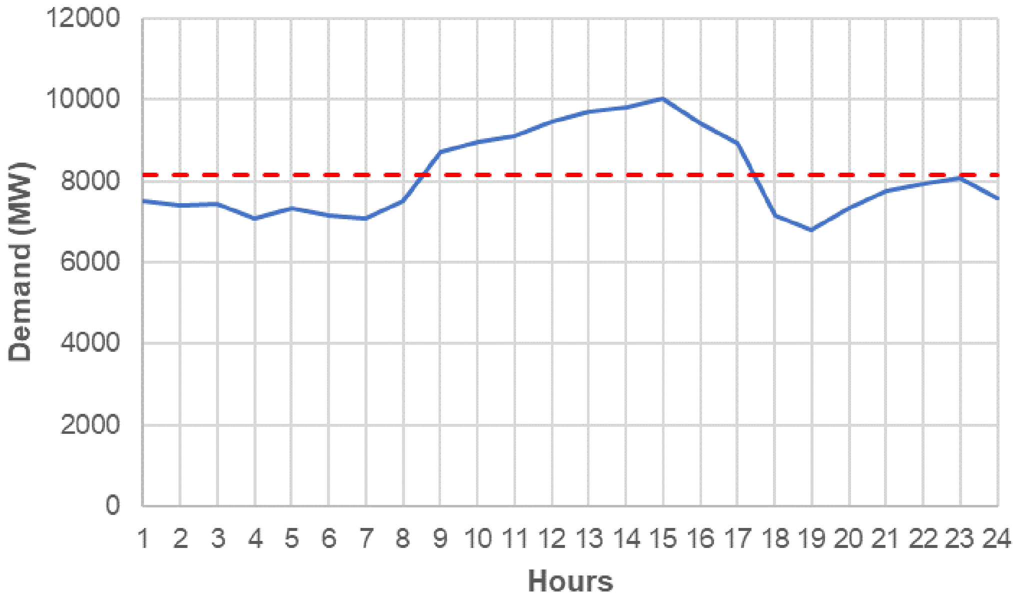


Figure - 2.1: Hourly Demand Curve in Summer (23rd May 2020)

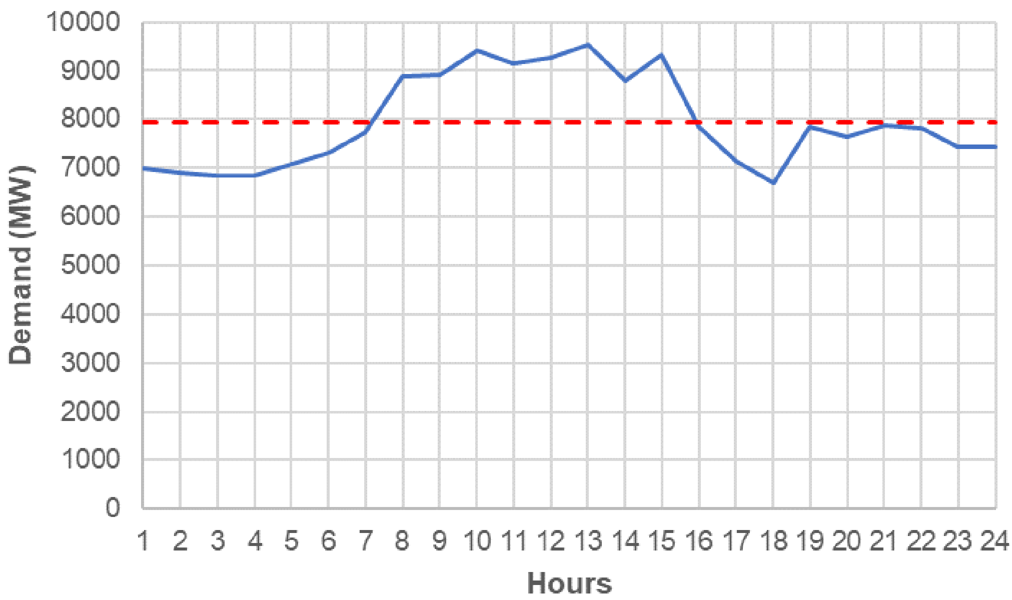


Figure - 2.2: Hourly Demand Curve in Monsoon (07th Sep 2020)

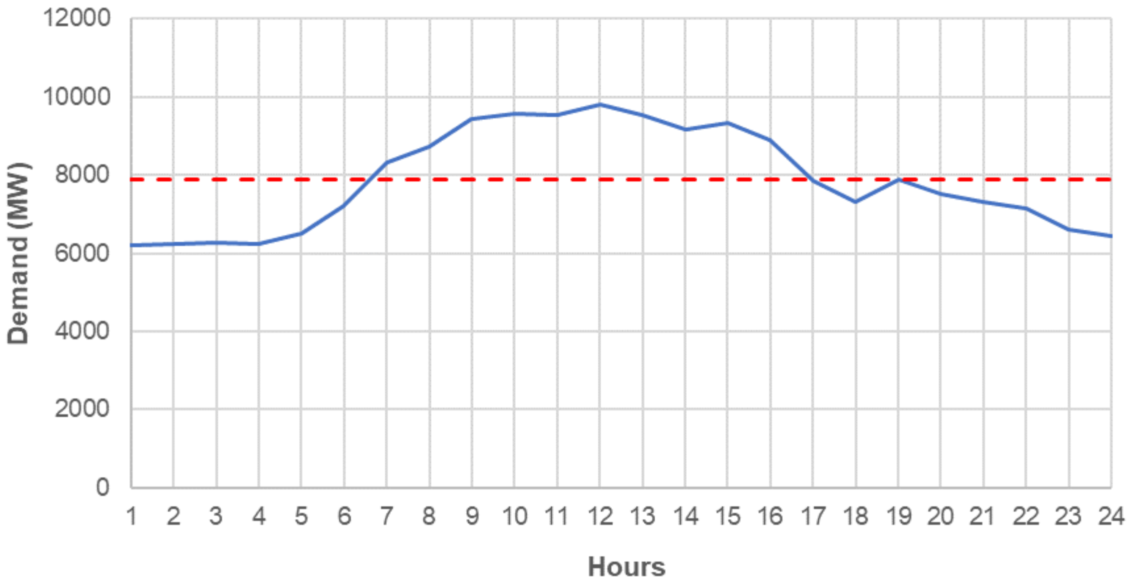


Figure - 2.3: Hourly Demand Curve in Winter (30th Jan 2021)

As seen from the above figures, peak demand occurs typically for a duration of about eight to nine hours in a day during 0800 hours to 1700 hours. The peak demand during the above period could be met to a certain extent by the proposed capacity addition in the solar plants and other non-conventional sources of energy. However, the entire peak demand during the early morning hours and late evening hours cannot be met from the solar plants, as the output during the above period will be significantly low. On the other hand, surplus peak power generated from the solar plants during the peak sunshine hours cannot be entirely used thereby result in wastage of clean & green energy. Therefore, a suitable energy storage system would be beneficial in storing the surplus energy generated during off-peak hours and utilizing the same during peak hours. Hence, it is recommended to develop pumped storage projects (PSP), which contribute to about 95% of the global energy storage to facilitate balancing of variable power from renewable energy sources.

2.9 Need for Proposed Kurukutti Pumped Storage HEP

As seen from Table - 2.6, the total installed capacity that is expected to be available by the terminal year of 5th Control period (i.e., 2028-29) is about 21,299 MW, as per the approved APERC order on Load Forecasts & Resource Plans for the 4th & 5th Control Periods, Apr 2019. Considering the additional planned solar capacity addition of 10,000 MW, the total installed capacity that will be available for meeting the demand in the state of Andhra Pradesh will be about 31,299 MW vis-a-vis projected peak power demand of 24,633 MW (Refer Table - 2.3). Therefore, a surplus capacity of about 27% is expected to be available considering the terminal year of 5th control period. However, as explained earlier, the entire installed capacity will not be available for meeting the peak demand due to non-availability of generation from hydel stations during summer season and drought years, seasonal and hourly variation of power output from renewable energy sources and non-availability of power from a few thermal power stations due to non-availability of coal and unscheduled outages/maintenance activities.

Necessity of Pumped Storage Project(s) in Andhra Pradesh

The total capacity of renewable energy/non-conventional energy sources is expected to be about 20,301 MW, which constitutes about 65% of total capacity in Andhra Pradesh by 2028-29. Currently, there is no mechanism / energy storage system available in the state of Andhra Pradesh to facilitate energy storage required for ensuring grid stability. Thus provision of adequate capacity of pumped storage scheme in Andhra Pradesh enables to plan for required additional installed capacity from wind and solar power that enables to:

- Meeting most of the demand significantly reducing load shedding
- Avoid wastage
- Allow export of energy, &
- Plan reduction in the use of coal by suitable generation scheduling

Advantages of Pumped Storage Project

Thermal plants are less able to respond to sudden changes in demand and may result in frequency and voltage instability. The coal or nuclear based thermal power generation cannot steeply rise or fall matching the load demand. The thermal power generators cannot normally be shut off in the night and brought on line in the morning to match system loads. If the thermal power stations are to share base and peak loads, then the power system will be subjected to frequency excursions. Moreover the thermal plants in such conditions have to run at low loads for prolonged periods needing fuel oil support thereby increasing the cost of generation, which is not desirable and not recommended. In case of renewable energy sources like Wind and Solar power stations, it is essential to note that generation from Wind power varies from hour to hour and from season to season, often increasing after evening hours, particularly during monsoon season. Similarly, generation from Solar power is available only during day time, but also varies hourly and by season. The power generated from these sources at a certain hour on a future date of a year are uncertain.

The most reliable option for energy storage is development of pumped storage scheme, which utilizes the surplus power available during Off-peak period to pump up the water for storage and meets the On-peak demand by utilizing the stored water during peak demand. Along with balancing On-peak and Off-peak demands, a pumped storage scheme also helps in controlling electrical network frequency and stabilizing the operation of grid.

The benefits to the state by setting up of Kurukutti PSP is summarized below:

a) Peak Power Shortage: The development of a Pump Storage would address peak power shortage to the extent of 8.4 Million Units per day and help in giving an impetus to Andhra Pradesh with 24x7 power supply.
b) Stabilizing the Grid: The National Solar Mission would induct large quantum of renewable energy to the grid in the years to come and the Solar power would go off the grid by the end of the day. The pumped storage project (PSP) will be required for stabilizing the grid and in turn supporting the National Solar Mission and facilitate induction of renewable energy in to the grid.
c) Long Term Asset to the State: The state will own a state of the art Pump storage facility after the end of concession period of 40 years. The state will benefit from investment of the money and save its precious resources.
d) Time of Day Tariff and Smart Metering: The Time of Day Tariff with smart metering would be a reality in the next few years. The Pump Storage Scheme would give the option of maximizing revenue to the state, since it can bring in additional power online at very short notice anywhere in the grid.
e) Employment and Local Area Development: The setting up of a 1200 MW PSP project would provide employment to hundred plus technical staff and provide job opportunity to thousands during the construction phase.

Chapter - III
Basin Development

3.1 The Course of the River

Upper dam is proposed to be located across a minor nallah draining into Boduru Gedda river and lower dam is proposed across Boduru Gedda river. Boduru Gedda river, which is a tributary of Suvarnamukhi river originates at an elevation of about RL 1400 m near Serubandha Parbat located in Odisha State. It flows for a length of about 22 km and drains a total catchment area of about 102 km^2, upto its confluence with Pedda Gedda river near Mokhasadandigam village. After its confluence with Pedda Gedda river, it is known as Suvarnamukhi river and further flows for a length of about 72 km and joins Vegavathi river near the Madduvalasa Reservoir. The total catchment area of Suvarnamukhi river upto its confluence with Vegavathi river is about 1337 km^2.

Both Vegavathi river and Suvarnamukhi river are tributaries of Nagavali river, which drains a total catchment area of about 9510 km^2 and joins the Bay of Bengal near Bontalakoduru village in Srikakulam district.

3.2 Power Potential of the River Basin and Stages of Development

Suvarnamukhi river basin is a minor drainage basin originating in the Eastern Ghat mountain ranges. The topography of river basin is mostly flat, except for its initial reaches located in the hilly region and hence the economically exploitable power potential of the river basin is negligible. However, there is a huge potential for development of pumped storage schemes in the upper reaches of the river basin in Eastern Ghats where there is significant drop available in the river/nallah's within a short length.

3.3 Trans-Basin Diversion of Waters

Being a pumped storage project, the water will be recycled on a weekly basis between the upper and lower reservoirs located in Boduru Gedda sub-basin. However, water lost due to evaporation in upper and lower reservoirs of Kurukutti PSP, to the extent of 2.4 Mm^3 per annum could be replenished during monsoon season from yield generated within the lower dam catchment area. Thus, there will a marginal reduction in annual yield of Boduru Gedda river downstream of dam sites.

3.4 Fitment of the Scheme in the Overall Basin Development

This PSP envisages to utilize the available head between proposed upper and lower dams situated in the Eastern Ghat mountain ranges and envisages an annual utilization of about 2.4 Mm^3 towards recuperation of evaporation losses in Boduru Gedda/Suvarnamukhi river basin. Hence, the proposed PSP will not have any impact on the water availability for domestic water requirements in the downstream reaches of the river basin.

As explained earlier, the PSP is located in the minor east flowing river basins with negligible hydro power potential. However, the scheme will function as an energy storage scheme for the solar projects and will provide an additional peaking power of 1200 MW to the state, especially during evening/nights.

3.5 Fitment of the Scheme in the Power Potential Assessment Studies carried out by CEA

The proposed Kurukutti Pumped Storage Project is not covered in the power potential assessment studies carried out by CEA.

3.6 Effect of Future Upstream/Downstream developments on the Potential of Proposed Scheme

The Kurukutti PSP envisages recycling of stored water in the reservoirs for power generation. Hence, there will be no impact on the proposed scheme due to any future upstream/downstream developments.

3.7 Conversion of storage scheme to ROR, if any

The scheme is conceived as an energy storage system (i.e., pumped storage hydroelectric project) for the large scale solar parks currently under implementation in the state of Andhra Pradesh. Hence, it is not envisaged to operate the proposed scheme as Run-of-the-river hydel scheme.

Chapter - IV
Interstate / International Aspects

4.1 States/Countries Traversed by the River

Kurukutti Pumped Storage Project is proposed to be located across Boduru Gedda river, originating at an elevation of about RL 1400 m near Serubandha Parbat located in Odisha State. It flows for a distance of about 8 km within the state of Odisha and enters the state of Andhra Pradesh, near Chemidipatipolam village. It further flows for a distance of about 14 km and joins the Pedda Gedda river (near Mokhasadandigam village) and is known as Suvarnamukhi river, thereafter.

4.2 Distribution of catchment in states/countries and yields from the catchment of state/country concerned

The catchment area of Boduru Gedda river upto lower dam site is about 83 km^2. Out of the above catchment area, about 35 km^2 of catchment area lies in the state of Odisha and remaining catchment area lies in the state of Andhra Pradesh. Considering the respective catchment area contribution, about 42% of total annual yield upto proposed lower dam site is expected to be realized from the catchment area situated in Odisha. Balance 58% of annual yield is realized from the catchment area situated in Andhra Pradesh.

4.3 Effect of the following on the project

a) Inter-state agreement on sharing of waters, sharing of benefits and costs, acceptance of submergence in the upstream state(s)

Currently, there is no allocation/decision made on sharing of water in Nagavali river basin between Andhra Pradesh and Odisha. However, based on the discussions made during the meeting between the Chief Minister of Andhra Pradesh and Chief Minister of Odisha at Hyderabad held on 15th of December 1978, an agreement was reached between the two states for utilization of 1) Nagavali river, 2) Jhanjavati river, 3) Bahuda river, 4) Neradi Joint Project and 5) Joint Minor Irrigation Schemes (Refer Annexure - 4.1). The agreement reached between Andhra Pradesh and Odisha for Nagavali river is reproduced below:

"Gaugings are being done at the Odisha Andhra Pradesh State Border to determine the yield from Nagavali river. However, it is agreed on adhoc basis that Odisha can plan its

projects utilizing upto 20 TMC on Nagavali river. The proposed utilization by Odisha affects the existing irrigation through diversion works and river channels in Andhra Pradesh territory. To protect the existing irrigation and develop some additional ayacut it is agreed on adhoc basis that Andhra Pradesh can plan Thotapalli storage reservoir scheme utilizing 16 TMC of water including lake losses. This scheme does not involve any submersion of Odisha territory".

As per the agreement, utilization of Nagavali river water between the two states has been made on adhoc basis from the Nagavali river itself. However, there is no allocation made between the two states or any restrictions imposed on the utilization of water from tributaries / sub-basins.

As explained earlier, Kurukutti PSP is proposed to be located across Boduru Gedda river, a tributary of Suvarnamukhi river, within the administrative boundary of Andhra Pradesh, which is the downstream riparian state. Further, being a pumped storage project, there is no water utilization envisaged from the project, except annual utilization of 2.4 Mm^3 towards recuperation of evaporation losses from the reservoirs. All the major components of project and submergence due to construction of reservoirs are confined within the state of Andhra Pradesh. Hence, no interstate issue on sharing of water, benefits and cost is involved.

b) Inter-state adjudication

Since this project is within Andhra Pradesh state, no inter-state adjudication is involved.

c) Interstate aspects of territory, property etc. coming under submergence, oustees rehabilitation, compensation etc.

As mentioned above project is within Andhra Pradesh state, no interstate aspects of territory, property etc. coming under submergence, oustees rehabilitation, compensation etc is involved.

d) Inter- national aspects if any

The project is at a radial distance of 85 km from the coast line (Bay of Bengal) .The project area is not falling close to international boundaries or the coast line and hence no international aspect is involved.

4.4 Existing riparian use, quantum of water presently utilized, commitments for ongoing projects, plans for future development, balance share of the state/country and proposed utilization by this project

Both upper and lower dams of the project are proposed to be located in Boduru Gedda sub-basin of Suvarnamukhi river and does not envisage any consumptive use of water, except for recuperation of evaporation and transit losses. The total annual quantum of water lost for both the reservoirs has been estimated to be about 2.4 Mm^3.

Water utilization upstream of both reservoirs in the catchment area is currently limited to domestic consumption towards drinking and irrigation requirements of adjoining villages. Thus, implementation of above project is unlikely to have any adverse impact on the existing/future water demands in the catchment areas. Considering the marginal drawal envisaged towards recuperation of evaporation losses in the reservoirs, there will be no major impact on water availability in the downstream areas.

Annexure - 4.1

Proceeding of the Meeting Between The Chief Minister of Andhra Pradesh and Odisha at Hyderabad on the 15th of December, 1978

The following were present :

	Andhra Pradesh		Odisha
1.	Dr. M. Channa Reddi, Chief Minister	1.	Sri Nilamani Routray, Chief Minister
2.	Sri. G. Raja Ram, Minister for Finance and Power.	2.	Sri Pratap Chandra Mohanty Minister of Revenue and Power
3.	Sri. G.V. Sudhakar Rao, Minister for Major Irrigation and Commercial Taxes	3.	Sri Prahallad Mallik, Minister for Irrigation.
4.	Sri I.J. Naidu, I.A.S. Chief Secretary	4.	Sri. B.M. Patnaik, Advoacate General
5.	Sri. S.R. Rama Murthy, IAS, Secretary to Chief Minister.	5.	Sri B. Ramadoari, IAS Secretary , Irrn & Power Deptt. Odisha.
6.	Sri P. Ramachandra Reddi, Advocate General	6.	Sri. A.K. Biswal, Secretary to Chief Minister.
7.	Sri C.N. Shastry IAS, Secretary, Irrigation and Power Deptt.	7.	Sri S.C. Tripathy, Chief Engineer, Irrigation.
8.	Sri M. Gopalkrishna, IAS Secretary, Primary and Secondary Education.	8.	Sri B. Mishra, Chief Engineer, Electricity.
9.	Dr. N. Tata Rao, Chairman, A.P.S.E.B.	9.	Sri M. L. Lath, Executive Engineer, Irrigation.
10.	Sri Satyanarayan Singh, Special Officer, Water Resources,		
11.	Sri D.V. Sastry, Advocate.		

After full discussions, the following agreement was reached:

1. NAGAVALI RIVER

Gaugings are being done at the Odisha Andhra Pradesh State Border to determine the yield from Nagavali river. However, it is agreed on adhoc basis that Odisha can plan its projects utilizing upto 20 TMC on Nagavali river. The proposed utilization by Odisha affects the existing irrigation through diversion works and river channels in Andhra Pradesh territory. To protect the existing irrigation and develop some additional ayacut it is agreed on adhoc basis that Andhra Pradesh can plan Thotapalli storage reservoir scheme utilizing 16 TMC of water including lake losses. This scheme does not involve any submersion of Odisha territory.

2. JHANJAVATI RIVER

In regard to Jhanjavati river the yield will be shared on 50:50 basis between Andhra Pradesh and Odisha. This yield is approximately assessed as 8 TMC. A revised project report for Jhanjavati utilizing approximately 4 TMC of water will be prepared by Andhra Pradesh providing gated spillway to keep submersion in Odisha territory to the minimum. The Government of Odisha agree to submersion subject to Andhra Pradesh paying compensation for land and property and rehabilitation expenditure according to Odisha Government norms prevailing during the period of acquisition and rehabilitation.

3. BAHUDA RIVER

a) The State of Odisha seeks clearance for full utilization of water in its territory from Bahuda river.

b) As utilizations in Odisha territory affects existing irrigation system through river channels and development of new ayacut in Andhra Pradesh territory, it is necessary to provide appropriate storage to protect such existing irrigation. Andhra Pradesh agrees to construct at its own cost such storage in its territory without involving any submersion of Odisha territory. The storage scheme, however, needs some other ancillary works for its functioning and as such Andhra Pradesh seeks concurrence of Odisha for the following.

   (i) The construction of regulator across Bahuda river below Kalingadola anicut near about kalabad village in Odisha territory with submersion in river bed and protected by flood banks.

   (ii) The construction of a second regulator on Boginadi near Sappanga village in Odisha territory with submersion in river bed and protected by flood banks.

   (iii) The construction of a diversion channel of appropriate capacity connecting the regulators (i) and (ii) above.

   (iv) The construction of a flood flow channel of appropriate capacity not exceeding 2,000 cusecs capacity from the regulator at Kalabad village upto Andhra Pradesh-Odisha border within Odisha Territory.

   (v) Odisha to make available to Andhra Pradesh 1.5 TMC (including lake losses) of water during June to December every year through the flood channel.

c) The State of Andhra Pradesh agrees to the construction of Schemes as at (a) by Odisha subject to protection of 1.5 TMC for schemes at (b) and the State of Odisha agrees to the scheme as at (b) subject to Andhra Pradesh meeting the cost of construction including cost of land acquisition.

d) Andhra Pradesh also agrees to utilization of the flood flow canal in Odisha territory for irrigation in its territory provided the extra water for such irrigation will be out of the share of Odisha and Odisha pays to Andhra Pradesh proportionate cost of flood flow channel.

4. NERADI JOINT PROJECT (VAMSADHARA)

Regarding Neradi Joint Project, Andhra Pradesh should immediately send the project report to Odisha for incorporating Odisha's requirements.

5. JOINT MINOR IRRIGATION SCHEMES

a) There are some minor irrigation schemes with head works in Odisha State and ayacut in Andhra Pradesh. In some cases, the ayacut is partly in Odisha and Partly in Andhra

Pradesh. The Odisha Government has claimed a sum of Rs. 6.49 lakhs from 1953 to 1972 and Rs. 3.04 Lakhs from 1972-77 towards the share of Andhra Pradesh for maintenance and repairs of the Irrigation systems in their territory. A sum of Rs. 6.00 lakhs has been paid to Odisha by Andhra Pradesh on adhoc basis subject to final adjustment.

b) The ayacut served in Odisha and Andhra Pradesh under the Joint Schemes is in the ratio 2:1 approximately. It is agreed that Andhra Pradesh will pay Odisha State for annual maintenance and repairs of joint minor irrigation schemes a sum calculated for the irrigated area in Andhra Pradesh territory under this system at the 2/3rds per acre rate fixed by the Government of Odisha as a State norm plus 16% towards establishment charges from 1953 onwards in full and final settlement of the share of Andhra Pradesh, in the expenses incurred by Odisha State on the maintenance and repairs of these joint sources. The amount of Rupees 6.00 lakhs will be adjusted against the share of cost upto 1977.

c) Any outlay on improvement and capital works of the system will be subject to prior concurrence of both the States and will be shared prorata to the benefits.

Sd/-
Dr. M. Channa Reddi,
Chief Minister, Andhra Pradesh

Sd/-
N. Routray,
Chief Minister, Odisha

Chapter - V
Survey and Investigation

5.1. Topographical Surveys

5.1.1 General

All the major components of the proposed project are covered under Survey of India (SoI) toposheet no. 65 N/2 available at 1:50,000 scale and the same has been referred to for preliminary assessment of the site and firm-up the extent of area required for topographical survey. In addition to the above, a small portion of the lower dam catchment area falls under SoI toposheet no. 65 J/14.

Further, detailed topographical survey of the project area has been carried out as per the relevant Indian Standard (IS) codes and “Guidelines for preparation of DPR’s of Irrigation and Multipurpose Projects, Ministry of Water Resources, 2010”.

5.1.2 Methodology

Field topographic survey has been carried out using state of the art instruments such as Electronic Total Stations, Differential Global Positioning Systems (DGPS), reflectorless EDM, Theodolites, level staves & calibrated tapes. All the equipment / instruments and measurement devices used for carrying out topographical surveys have been properly calibrated before commencement of field work to reflect factual values. In order to achieve accuracy in survey, primary control points were established by DGPS equipment adapting datum and projection and traversing was done by Total Station equipment all over the project area in between the primary control points at suitable intervals depending upon the topography of the locality, so that the control points are inter-visible. Survey was carried out all along the control points already established in the whole project area starting with a Temporary bench mark and closing to the same bench mark or another bench mark depending upon the availability of bench marks in and around the project area.

The horizontal angles were observed on two zeros (0 - 180) using Electronic Total Station. Precision targets with optical centering and leveling devices were used at the stations observed. The distances were measured twice (back and forward) by using electronic distance meter in-built in Total Station, which will give the measurements to the 2 mm accuracy. All the traverse lines were commenced and closed on traverse station of adjoining lines. The accuracy was determined by noting the closing error in the Easting and Northing coordinates.

5.1.3 Reference Benchmark

The Survey of India (SoI) permanent benchmark located at Mandal Revenue Office (MRO) at Bobbili, which is located at a distance of about 45 km from project site has been taken as reference benchmark. Details (coordinates & elevation) and photographs of GTS Benchmark at MRO office, Bobbili is furnished below:

MRO OFFICE BOBBILI COORDINATES:

INDEX	EASTING	NORTHING	ELEVATION	LAT DMS	LONG DMS	REMARKS
SOI	747567.865	2055165.022	136.254	18°34'21.76902"N	83°20'44.66904"E	MRO OFFICE AT BOBBILI

5.1.4 Plan Control & Traverse Points

Horizontal and vertical control points for the area being surveyed have been established with reference to the nearest GTS Control Pillars and SoI Benchmark located at Bobbili. Horizontal and vertical control points have been fixed by Triangulation Method. DGPS traversing is made with advanced DGPS reservoirs having long-range transmitting and reception capabilities. Details of a few benchmarks established in the area are furnished in Table - 5.1.

Table - 5.1: Control Points near Project Site

ID	Northing	Easting	Elevation (RL in m)
BASE	2059160.083	719318.808	260.547
GCP1	2062720.221	716037.492	910.928
GCP1A	2062730.729	716045.352	911.067
GCP3	2060137.726	713570.268	1134.424
GCP3A	2060143.701	713565.952	1134.545

The benchmarks established at site with reference to GTS benchmarks are written/etched on the permanent structures, sheet rocks, pillars, ground level reservoirs, the details and photos are furnished herewith.

The list of traverse points considered for topographical survey is furnished in Table - 5.2.

Table - 5.2: List of Traverse Points

Control Point	Elevation (RL in m)	UTM Coordinates	
		Northing	Easting
NC1	259.033	719477.326	2059045.072
NC2	255.201	719552.057	2059005.650
NC3	253.050	719642.126	2059002.593
NC3/1	253.250	719676.250	2059005.905
NC4	253.870	719696.953	2059011.901
NS1P	259.556	719306.526	2059159.590
NS2	259.952	719184.631	2059067.149
NS3	261.149	719406.332	2059096.547
NS4	264.308	719298.606	2059266.427
NS5	262.036	719272.135	2059260.117
NS6	267.589	719023.724	2058952.627

5.1.5 Temporary Benchmarks (TBM's)

The list of temporary benchmark points establish at project site is furnished in Table - 5.3.

Table - 5.3: List of TBM's

BM Number	Elevation (RL in m)	UTM Coordinates	
		Northing	Easting
TBMP1	257.136	720548.925	2059521.860
TBMP2	250.514	721168.810	2059804.550
TBMP3	249.757	721188.438	2059816.136
TBMP4	212.419	722371.001	2060012.741
TBMP5	212.405	722375.382	2060018.394
TBMV2	258.526	719546.792	2059028.973

BM Number	Elevation (RL in m)	UTM Coordinates	
		Northing	Easting
TBMV3	257.512	719890.856	2059135.862
TBMV3	1141.422	713780.669	2060087.922
TBMV5	949.682	715273.346	2059295.471
TBMV6	880.890	715615.171	2059789.433
TBMV7	880.748	715609.077	2059789.664
TBM	955.435	715239.878	2059287.549
TBM	319.475	717388.513	2058312.062
TBM	260.565	719297.754	2059155.002
TBMP	254.241	720347.317	2059405.698

5.1.6 Spot Levels & Other Levels

Spot levels have been taken at nodes of a grid with appropriate size (50 m / 10 m) as required for respective project components. Finer grid has been adopted wherever required to represent all local features. The grid established for spot levels is essentially perpendicular and parallel to the established Baseline. The levels have been captured at required intervals using DGPS equipment's after marking control points at prominent locations through traversing. All spot levels/elevations along with contours have been plotted in the field drawing and their trend checked in situ with the general ground profile and terrain. Contours at required interval have been plotted as per requirement. Similarly, water levels and bed levels along the river / Nallah have been recorded/surveyed along with date of survey. High flood level details along the river have been obtained from local enquiry and/or flood marks prevailing at site.

5.1.7 Features

All existing features; natural or man-made and whether of a temporary or permanent nature, have been incorporated in the topographical survey and shown on the survey drawings. Locations of key features have been established by site triangulation network. All the existing topographical features such as overhead power lines, electric poles, Trees, nallas, water courses, roads, buildings, river, colony, camp area, camp offices, dump area temporary and permanent structures, ponds, wells, etc. were surveyed and shown on the drawings. Different layers have been used to denote various entities like contours, road, spot levels, river bank, trees, forest and revenue boundaries, stop dams, bridges etc. in the survey drawings. Spot levels have been taken at all ridges, valleys and definable points.

5.1.8 Topographical Survey Drawings

The drawings were prepared to different scales as per project requirement using latest version of Auto-CAD Civil 3D, so that the final map is legible, clear & presentable. All descriptive features are printed on the map. The following topographical survey drawings have been prepared for the project:

Table - 5.4: Topographical Survey Drawings of Project Area

Sl. No.	Drawing Number	Drawing Title
1.	TCE.12058A-CV-3005-LM-31104	River Survey - LS & CS (Upper Dam) Downstream
2.	TCE.12058A-CV-3005-LM-31105	River Survey - LS & CS (Upper Dam) Upstream
3.	TCE.12058A-CV-3005-LM-31106	River Survey - LS & CS (Lower Dam)
4.	TCE.12058A-CV-3005-LM-31107	Contour Plan of Upper and Lower Dams
5.	TCE.12058A-CV-3005-LM-31108	Contour Plan of Upper and Lower Reservoirs
6.	TCE.12058A-CV-3005-LM-31109	Contour Plan of Powerhouse & Switchyard

A 3-dimensional view of the entire project area has been prepared using actual topographical survey data and the resulting image indicating the terrain comprising hills, and valleys/streams is shown in Figure - 5.1.

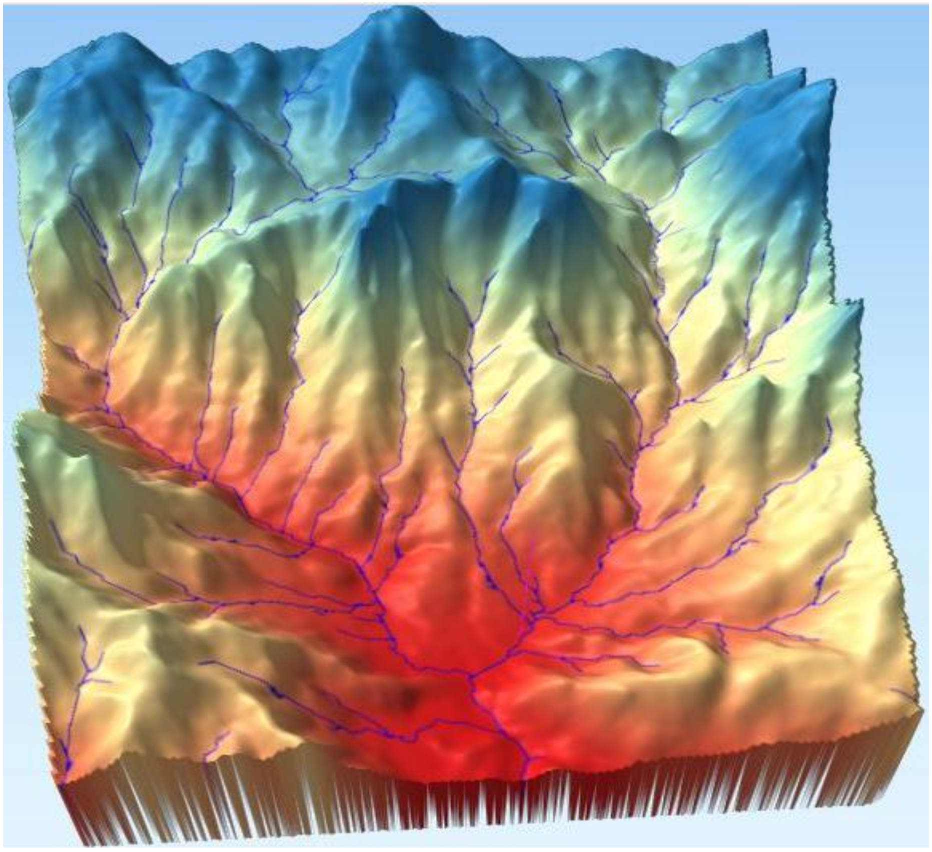


Figure - 5.1: 3-Dimensional View of Project Terrain

5.1.9 Photographs

A few photographs taken during the course of field work are provided in the following pages.

Lower Reservoir Area

Upper Reservoir Area

Survey At Higher Reaches of Project

Low Level Causeway 6.3 km Downstream of Lower Dam (Near Dandigam)

5.2. Archaeological Surveys in the Reservoir Area

Topographical surveys have not indicated presence of any archaeological monuments in the project area.

5.3. Communication Surveys

The project area is located at high altitude and in a remote location and tele-communication facilities (mobile) are limited, as there are not much inhabitations nearby. So, it has been recognized to improve the tele-communication facilities by provision of extra facilities.

5.4. Geology and Geo-technical Features

5.4.1 Geology

The proposed Kurukutti PSP is located in the Eastern Ghats region in Salur Taluka of Vizianagaram District, Andhra Pradesh. Geologically, the Eastern Ghats are older and more complex than the Western Ghats and is composed of various type of rock, including khondalites, charnokites, metamorphic gneiss, granite gneiss, and quartzite. Iron ore, limestone, and bauxite can also be found in the range. In terms of its structure, the Eastern Ghats has strike-slip faults and thrusts along its ranges. The Eparchaean Unconformity is the main discontinuity of the Eastern Ghats, which is situated in the Tirumala Hills and occurred due to extensive erosion along the hill.

5.4.2 Geomorphology

Geomorphologically the area is in Eastern Ghats, having numerous hill ranges/ridges with dome and basin structures and intermittent valleys. The hill ranges vary in elevation from 465 m to 1300 m, trending in NE-SW and E-W direction. There are many small streams and rivers originate/flows, draining the area. The main rivers are Vamsadhara, Mahendra Tanya, Nagavali, Gosthani, Champavati, Suvarnamukhi, Vegavati and Gomukhi. River Gosthani originates from Ananthagiri forest area. Suvarnamukhi River originates from the hills of Salur and flows in Easterly direction and joins Nagavali near Srikakulam. Vegavati originates from Pachipenta hills and flows parallel to Suvarnamukhi. River Gomathi originates in this region and flow North West of Salur.

The drainage pattern is mainly dendritic having moderate to high density. The drainage pattern indicates structural control. Boduru Gedda is a perennial stream originating from these hill ranges, and vast catchment area spreads over these hill ranges and idle site for constructing the dam and reservoir and generating hydel power.

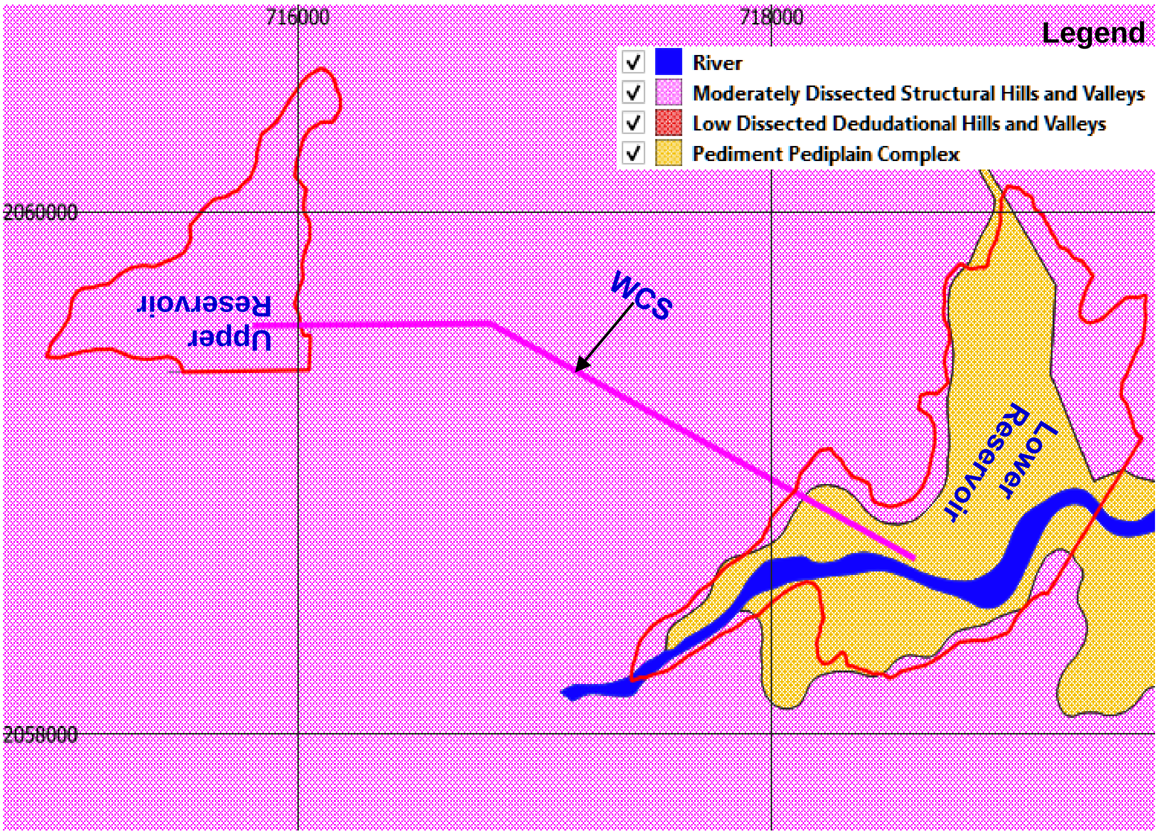


Figure - 5.2: Geomorphological Map of Project Area

5.4.3 Regional Geology

The Eastern Ghats Mobile Belt (EGMB) also referred to as the Eastern Ghat Granulite Belt, is a granulite terrain mainly made up of Khondalite, quartzite, calc-granulite, pyroxene granulite and charnockite. The EGMB has a trend of NE-SW and extends from Ongole in Andhra Pradesh to Brahmini River in Odisha. It stands as Ultra-high temperature (UHT) metamorphic belts. Three broad longitudinal zonations have been made in EGMB namely, (i) The Eastern Migmatite Zone (EMZ),(ii) Central Khondalite Zone (CKZ) and (iii)Western Charnockite Zone(WCZ). The EGMB hosts number of minerals of economic importance such as manganese, graphite, bauxite, apatite and gem stones. Many of charnockite varieties and leptynites are being exploited as dimension stone granites. The different rock types in the EGMB are classified into Khondalite Group and Charnockite Group, which constitute the Eastern Ghat Supergroup. The area falls in one discontinuous and isolated hillock system, which comes under Eastern Ghat Tectonic system of Archean Age group. The study area is characterized by Eastern Ghats mobile belt. Garnet-sillimanite-biotite gneisses, hypersthene granites (Charnockites), garnetiferous granites (Leptynites), quartizites and pegmatite's are the chief rock types that occur as massive formations in the study area. The intermediate and acid charnockites form large bodies associated with khondalites. These Charnockites are grey to greasy in colour, medium to coarse grained with Quartz, Plagioclase feldspar, pyroxenes, garnet, biotite and Fe-oxides. The Eastern Ghats complex mainly comprises of Khondalite suites with a set of sub-suites. Intrusive activity might have caused migmatisation. The terrain must have subjected to cycles of metamorphism.

The local geology shows the occurrence of Granite gneisses, Charnockite, Khondalite, Quartz and soil. The following is the local stratigraphy of the project area. Quartz (intrusive), Granite gneisses, Charnockite (Charnockite Group), and Khondalite is the dominant rock type of the area. It is olden metamorphic schistose rock with garnet, sillimanite, graphite, Feldspar, Quartz and Biotite as essential minerals and Garnets, Mica, Hornblends are accessory minerals. Granite gneisses are fresh looking light coloured, showing gneissosity consisting Quartz, Feldspars, Garnet and Sillimanite schist. Alternatte alignment of leuco and melanocratic minerals attains gneissic property. Garnet is also observed as discrete grains of reddish, brown, colour and equigranular texture. The formation is highly structural disturbed with joints, fractures.

Local Geology of the Area

Geological succession of the area is given as follows:
The area forms a part of the Archaean metamorphic belt of the Eastern Ghats and is constituted of charnockitic rocks, khondalites granitic gneisses and granites.

Geological succession of Salur Mandal, (A.P.)

Age	**Group**	**Rock Types**
Recent		Alluvium and Soil.
Pleistocene(?)		Laterite-liminite and ochre
Miocene (?)		Sandstone
		Pegmatite and quartz veins.
		Granite and Granite gneisses
Archaeans	**Charnockite Group**	Hypersthene Gneisses
		Granite gneisses.(charnockite)
Archeans	**Khondalite Group**	Garnet sillimanite gneisses(khondalite)
		Garnet granulites- Mn.Ore (Hor-1)
		Garnet granulites-Mn.Ore (Hor-2)

Coarse grained quartzite
Feldspathic quartzite (Hor-3)
Coarse grained quartzite
Garnet-sillimanite-gneisses
(Khondalite)

The mutual relationship of the rocks of khondailte suite with those of charnockite suite is not clear as there are no field evidences within the mapped area for establishing their relative stratigraphic position. The project area consists largely of khondailte suite of rocks with minor bands of charnockite suite of rocks. The project area lies along the eastern margin of the Eastern Ghats. The chief rock types encountered are porphyroblastic-hypersthene-biotite-gneiss (intermediate to acid charnockites), pyroxene-granulite (basic, charnocldtes), garnetiferoussillicianite-gneiss, quartzite, diopside granulite and gneiss. Porphyritic-gneissicgranite and a group of migmatised rocks are derived from the above due to the influx of quartzo-felspathic material. The regional strike of foliation veers from N.N.W. - S.S.E. to N.W- S.E., with steep easterly dips.

Distribution and Description

I. KHONDALITE GROUP:

The oldest recognizable rocks in the area are a group of meta-sediments comprising the argillaceous, arenaceous and calcareous members. The arenaceous meta-sediments are represented by quartzites, while the argillaceous and calcareous ones, by quartz-feldspar-garnet-sillimanite-gneisses and diopside granulites and gneisses respectively. Of these three types, the arenaceous member predominates over the other two.

1) Diopside-granulites and gneisses:-

Calc-granulites and gneisses occur as small lenticular bands in association with quartzites and khondalites. The rocks are recognized in the field by their characteristic ribbed weathering. The calc-silicate rocks are medium gained, equal-granular, granulitic and at places gneissose-due to the, alignment of mineral constituents. They consist of diopside, plagioclase and Sphene with associated garnet and spinel. They exhibit intense drag folding and intrusion of quartz-fedlspathic veins.

2) Quartzites:-

The quartzites are interbedded with garnetiferous-sillimanite gneisses (khondalites) which occur as narrow, persistent bands which stand out prominently, within the quartzites. The interbedded nature of khondalites and quartzites and their persistence in their strike direction for several kilometers, is suggestive of the Sedimentary nature- of the two rock types.

The quartzites are coarse gained, greyish white and massive. Quartz is the chief mineral, the other minerals being, limonitised reddish brown garnet, yellowish to green epidote, one or two grains of pyrite and highly kaolinised feldspar. The epidote appears to have been developed along the joint planes. The quartzite is highly jointed and at places brecciated.

3) Garnetiferous-sillimanite-gneiss (Khondalites):

The khondalites are medium, to fine grained, pink to reddish, and gneissose, consisting of quartz, feldspar, garnet and sillimanite. Quartz is the predominant constituent occurring as irregular grains. Feldspars are white to greyish white and are usually highly kaolinisce. Garnet is usually reddish brown which becomes yellowish brown on intense limonitisation. Sillimanite occurs as fibres and needles aligned parallel to the foliation planes.

II. CHARNOCKITE GROUP:

In the area under report hypersthene bearing granulites and gneisses referable to as charnockitic rocks are widely developed. Porphyrobiastic-hypersthene-gneisses consisting of feldspar, quartz, hypersthene, biotite and garnet are the most abundant rocks. Medium-grained, non-porphyiritic, dark coloured pyroxene-granulites occur as bands, lenses and ribbons in the former. The latter are referred here as basic charnockites, while the others as acid to intermediate charnockites.

1) Pyroxene-granulites:

Thin lenticular bands, lenses and streaks (of unmappable dimension)of pyroxene-granulites occur within the widely distributed acid to intermediate charnockites. The contact between the two rock types is gradational, though the sharp contacts are not uncommon. The pyroxene-granulites are dark-coloured, fine to medium grained and granulitic, consisting essentially of pyroxenes, feldspar, biotite and quartz.

2) Porphyroblastic-hypersthene-biotite-gneisses (intermediate & acid Charnockites):

These are the prevalent rock types of the charnockitic group. In striking contrast to the pyroxene-granulites, gneiss charnockites are light coloured and are characterised by greasy luster. They are also marked by irregular distribution of the constituent minerals. Feldspar quartz and hypersthene constitute the essential minerals and biotite, and garnet as secondary minerals and the iron-ores as the accessories. These rocks re-coarse to medium grained, bluish grey to bluish black with prominent development of feldspar porphyroblasts. The porphyroblasts are rectangular, augen-shaped, and irregular and are usually aligned in NNW - SSE to WSW- ESE directions. Garnets are well developed and segregated at places to form nuggets. With the increase of the content of quartz and feldspar and concomitant decrease in the amounts of mafics, the intermediate charnockite grade into acid types. The junction between the two types is not well-defined making it difficult to delineate them separately on the map. The porphyroblastic-hypersthene-gneisses have been intruded by gneissic granite which occurs as narrow veins cutting across the gneissosity of the host rocks.

3) Porphyroblastic-grarnetiferous-biotite-gneisses:

Porphyroblastic-garnetiferous-biotite-gneisses consisting of porphyroblasts of feldspar, quartz garnet and biotite are found with thin lenticular bands lenses and streaks of biotite-rich gneissose roof with green spinel. These rocks have been intruded by porphyritic-gneissic-granite. The contact between the garnetiferous-biotite-gneiss and porphyritic gneissicgranite is gradational, one merging into other. The patches of garnetiferous-biotite-gneiss are also rendered porphyroblastic near porphyritic gneissic granite, by the development of small feldspar porphyroblasts giving rise to porphyroblastic-garnetiferous-biotite-gneisses. The porphyroblasts are augen-shaped and aligned parallel to gneissosity. The porphyroblastic garnetiferous-biotite-gneiss is greyish black, medium grained, and gneissose’s consisting of feldspar quartz, biotite and garnet.

4) Porphyritic gneissic granite:

The intrusion of the porphyritic gneissic granite is along the foliation planes of the biotite gneisses. The porphyritic gneissic granites occur in veins which traverse the biotite-granite in all directions suggesting their mobile nature, at the time of intrusion. The lit-par-lit injection of the porphyritic granite along the foliation planes of biotite gneisses, gives rise to typical composite gneiss of migmatitic origin. With the partially digested bands of biotite gneisses, porphyritic gneissic granite shows interning in different stages, with, thin veins of pure uncontaminated portions, section rocks have been intruded by pegmatite veins.

The rock consists of elongated bluish grey grains of quartz, white feldspar, garnet disseminated throughout the rock and biotite in small flakes.

5) Pegmatite and quartz veins:

Quartz veins and pegmatite's represent the youngest igneous rocks in the area. They were intruded into the earlier as conformable veins along the foliation plans. Discrepant rolling of the veins is also noticed at a few places, the pegmatite. A consists of coarse crystals of quartz and feldspar. The feldspar is white to grey in colour. Quartz veins consist almost entirely of bluish quartz.

6) Laterite:

Thin capping of laterite is noticed and the laterite appears to have been derived from the charnockites and quartzites by residual weathering. Near the contact partially lateritised charnockites and quartzite's are found indicating a transition from unaltered charnockite and quartzite to lateritisied ones. The laterite is brownish black on the surface and reddish brown when freshly out.

7) Alluvium and soils:

The low lying areas and narrow valleys are covered by brown sandy and clayey soils, derived from the weathering of gneisses and quartzite's and subsequently, transported. The thickness of soil varies from 1 to 5 m.

Structural Features

The regional strike of the foliation in the area is N.W -S.E. and dips are towards northeast at an angle ranging from 40^0 to 80^0. The foliation in the khondalite group of rocks is in conformity with the bedding as indicated by the alternating bands of quartzite and khondalites.

The calc-gneisses are folded into minor antiforms and synforms plunging 30^0 to 40^0 E. Well-developed joints are seen at many places trending generally in N.W.-S.E. and N.E.- S.W. directions and are mostly vertical. Joints are seen in all rock types.

The area mapped lies along the eastern margin of the Eastern Ghats. The preponderance of quartzites over the Calc-granulites and garnet-sillimanite-gneiss of the khondalite group indicates that the sediments deposited in this part of the area, were dominantly arenaceous in nature. The argillaceous and calcareous sediments occur only as intercalations. The ancient sediments were subjected to severe folding and were syntectonically metamorphosed under the granulite facies conditions to give rise to the present day khondalite suite of rocks.

In the later stages of metamorphism the meta-sediments were invaded by quartzo-feldspathic material along their schistose planes resulting in the development of felspathised khondalites and garnetiferuus-biotite gneisses. The basic charnockites were also affected by these quartzo-feldspathic materials giving rise to intermediate and acid charnockites.

The granitic rock at places is found to contain hypersthene and biotite, apparently assimilated from the invaded rocks and thus assumes the composition of acid charnockites. The field evidences indicate that the gneissic granite is younger than the porphyroblastic-hypersthene-gneisses. As regards the relationship with the meta-sediments, lense-shaped inclusions of quartzite's are found along the foliation planes of the hypersthene gneisses as noticed on a small mound.

The Archeans are directly overlain by the Tertiary Sub-Recent and Recent formations viz. laterite, alluvium and soils. The complete absence of rock formations of intervening ages point to the remarkable stability of the area since the Archean times.

Detailed geological mapping and geotechnical investigations of the project area will be taken up during DPR stage to decipher the stratigraphy and structure and the mode of the origin.

Geological map and lithology map of the project area has been downloaded from web portal of Geological Survey of India (Bhukosh) and proposed locations of upper and lower dams/reservoirs and tentative alignment of water conductor system has been super-imposed on the maps and are shown in Figures - 5.3 and 5.4 respectively.

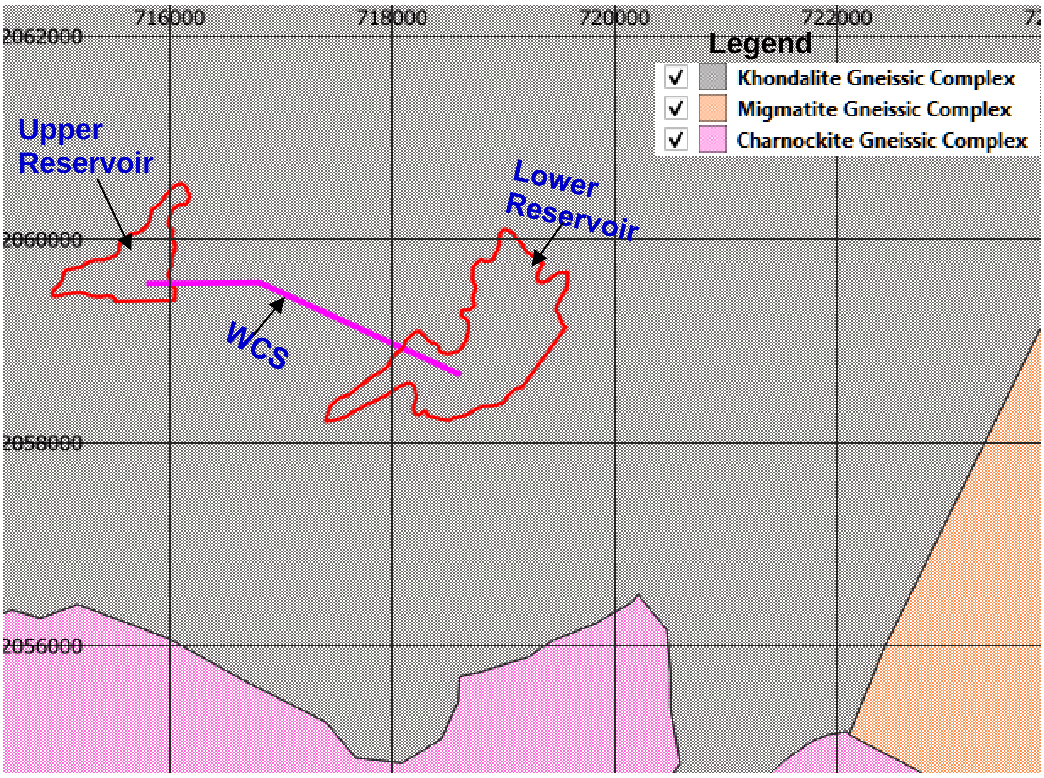


Figure - 5.3: Geological Map of Project Area

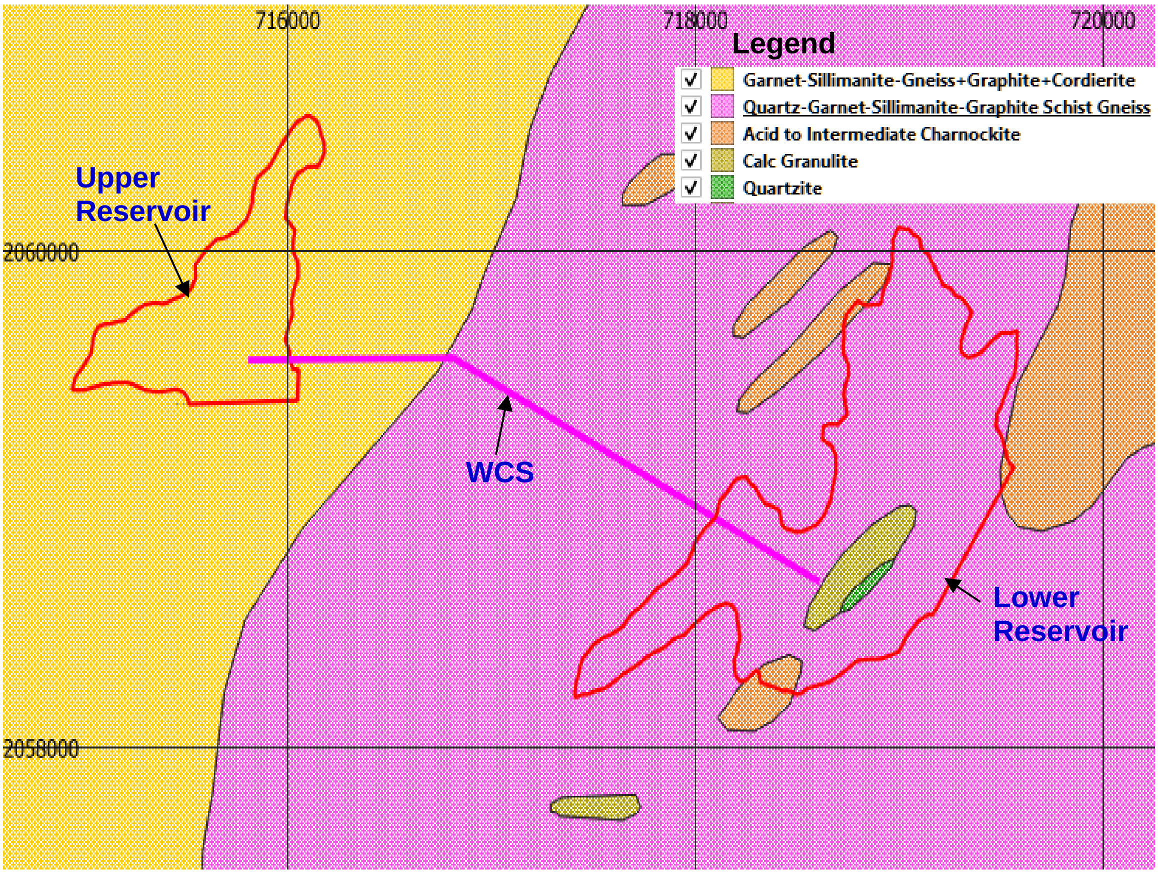


Figure - 5.4: Lithological Map of Project Area

5.5. Seismicity

The project area falls in Zone III as per IS-1893 (Part 1) 2002, Seismic Zoning Map of India (Refer Figure - 5.5). There are no major thrusts or fault reported here.

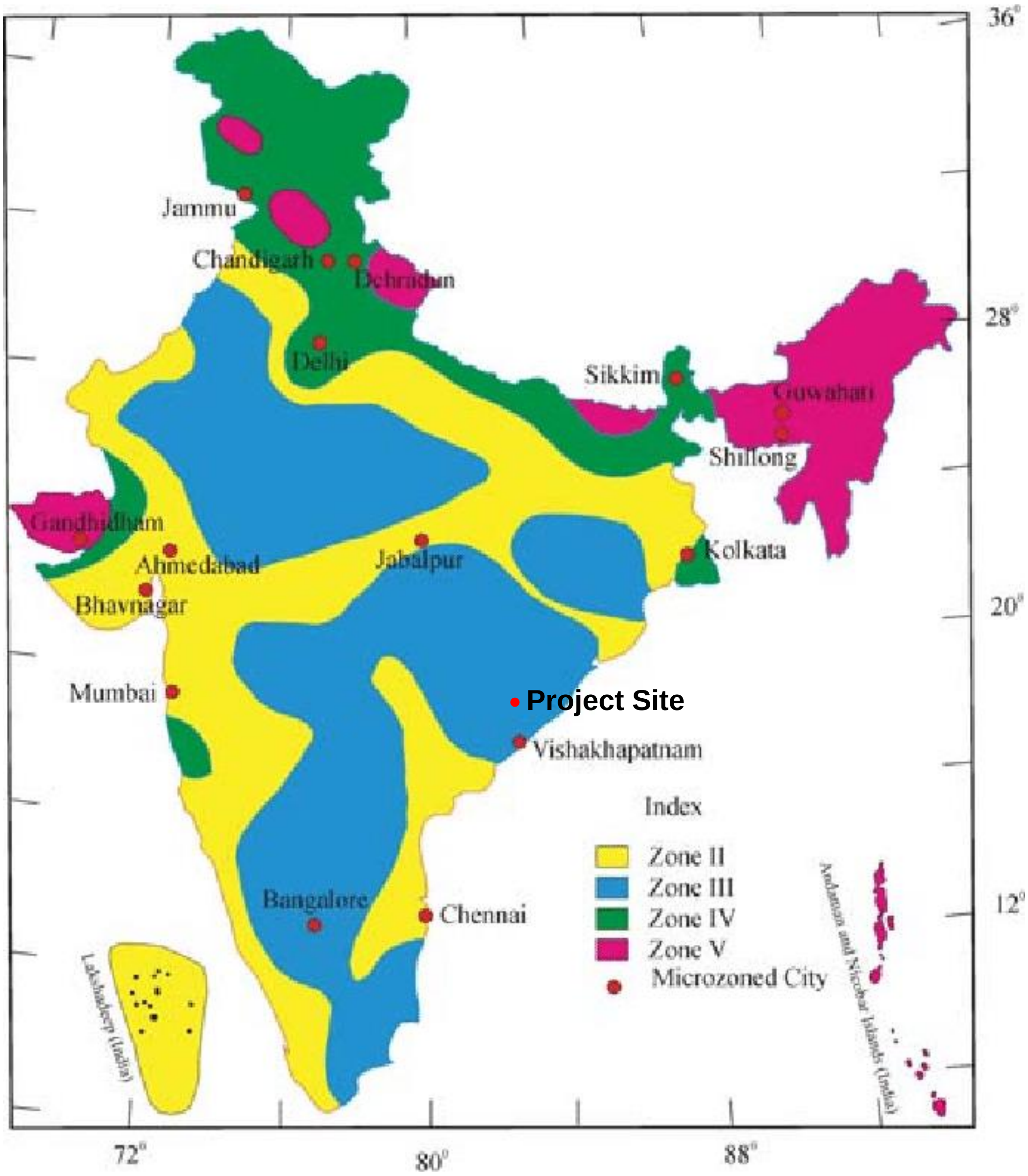


Figure - 5.5: Seismic Zoning Map of India

5.6. Site Geology

The project envisages construction of a 71 m high (above deepest river bed level) and 680 m long upper dam and 62 m high (above deepest river bed level) and 740 m long lower dam, 3.65 km long water conductor system and a shaft type powerhouse. The area around the proposed project has undulating topography with elevation ranging from 1000 m to 250

m. Drainage pattern is dentritic with moderate slope covered by veneer of soil. Country rock prevailing in the area is mainly of Khondalite group and to a small extent of Charnockite group (Refer Figure - 5.4).

Upper dam/reservoir is proposed on a rocky ridge near Chemidipatipolam village. Here, bed rock of Khondalite is exposed on the hill ridges and also on the slopes. The valley is wide with few first order and second order streams draining the area. General strike of formation is NE-SW with 550 dip towards SE direction. The Lower dam is located near Kurukutti village across Boduru Gedda river. Here the river flows in the West to East direction. At proposed dam axis the river flows in a ‘v’ shaped moderately wide valley with moderate slopes. On the right bank is covered by silty clay material under terrace cultivation. The left bank is steep with veneer of soil/slope wash material. The bed rock is expected to be at shallow depth. The valley is covered by river bourn material and silty clay soil under cultivation. Bed rock is exposed on the hillocks. Depth of bed rock expected to be 2 to 5m deep at the proposed dam site. The bed rock is expected to be massive, blocky and strong to very strong. General strike of formation is NE-SW with moderate dip towards SE direction.

The headrace tunnel is aligned along West-East direction, thereafter it is aligned along NW-SE direction slightly oblique to the strike of the formation. The water conductor system would have super incumbent cover ranging from 25 m to a maximum of about 350 m. About 105 m deep, 10 m diameter open type surge shaft is also expected to be housed in strong to very strong Khondalite suite of rocks. Shaft power house is proposed near the lower reservoir and would be founded in blocky to moderately jointed and strong Khondalite rock formation. The TRT is aligned favourably in NW-SE direction perpendicular to the strike of the formation. No major geological surprise is anticipated at this stage. The proposed tailrace tunnel is expected to be driven in moderately to widely jointed, strong to very strong Khondalite rock formations. From the observation of surface exposures nearby it is presumed that larger part of the tunnels, pressure shaft and powerhouse would be in Class II Good Rock with pockets of Class 1 Very Good Rock and class III Fair Rock condition. Presence of localized pockets of Class IV Poor rock up to 10% of the length cannot be ruled out.

The type of rock formations expected for various project components is furnished in Table - 5.5.

Table - 5.5: Rock Formations of Project Components

Sl. No.	Project Component	Rock Formations
1.	Upper dam/reservoir, Intake & HRT	Garnet-Sillimanite-Gneiss+Graphite+Cordierite (Khondalite Group)
2.	Surge shaft, Pressure shaft, Powerhouse, TRT & Lower intake	Quartz-Garnet-Sillimanite-Graphite Schist/Gneiss (Khondalite Group)
3.	Lower dam/reservoir	Quartz-Garnet-Sillimanite-Graphite Schist/Gneiss, Calc Granulite& Quartzite (Khondalite Group) & Acid to Intermediate Charnockite (Charnockite Group)

5.7. Foundation Investigations

Foundation assessment of various structures has been made based on the regional geology map and observations made during site visit. Detailed investigations will be carried out during DPR stage to assess the foundation and rock parameters before finalization of location and alignment of project components.

5.8. Hydrological and Meteorological Investigations

The following hydrological and meteorological data has been collected/obtained from various sources:

a) Rainfall
b) Climatic data
c) Gauged flows of Gosthani river at Kasipatnam gauging station
d) Gauge & discharge data of Boduru Gedda river at Dandigam
e) Siltation rate

Chapter - VI
Hydrology

6.0 General

Kurukutti pumped storage project is proposed to be located in Vizianagaram district of Andhra Pradesh State. Two dams are proposed under this scheme. The upper dam is proposed near Chemidipatipolam village, Salur Taluka of Vizianagaram district and Lower dam is located near Kurukutti village, Salur Taluka of Vizianagaram district. Hydrological Studies have been carried out in order to:

a) Assess water availability at the dam sites.
b) Estimate design flood for spillway.
c) Estimate diversion flood.
d) Assess sediment inflow to estimate storage loss of the reservoir after 100 years of operation.
e) Assess evaporation losses based on climatic characteristics of the region.

Kurukutti project is a pumped storage project and hence no consumptive use of water has been envisaged for power generation. Both the upper and lower reservoirs with a combined capacity of about 51 Mm^3, have to be filled up once at the beginning of plant operation. However, any losses in the reservoir storage due to evaporation, transit and seepage etc, will have to be made up each year. The approximate reservoir losses (excluding seepage losses) are about 2.4 Mm^3 in a typical year.

River System and Basin Characteristics

Both upper and lower dams of Kurukutti PSP are proposed to be located in Boduru Gedda river/sub-basin, which is a tributary of Suvarnamukhi river. Boduru Gedda river originates at an elevation of about RL 1400 m near Serubandha Parbat located in Odisha State. It flows for a length of about 22 km and drains a total catchment area of about 102 km^2, upto its confluence with Pedda Gedda river near Mokhasadandigam village. After its confluence with Pedda Gedda river, it is known as Suvarnamukhi river and further flows for a length of about 72 km and joins Vegavathi river near the Madduvalasa Reservoir. The total catchment area of Suvarnamukhi river upto its confluence with Vegavathi river is about 1337 km^2.

6.1 Hydrological Inputs for the Project Planning

The following hydrological inputs have been considered for the planning of the proposed PSP:

a) Meteorological data
b) Rainfall data
c) Gauge discharge data
d) Lake evaporation
e) Sediment inflows
f) Flood inputs

6.1.1 *Meteorological Data*

The daily maximum and minimum gridded temperature data (1° x 1°) for the project region for the recent 30 years period during January 1991 to December 2020 has been obtained from Indian Meteorological Department (IMD). The mean annual temperature near project site is around 26.6° C and the climate is pleasant throughout the year. The highest maximum temperature observed during summer till date is about 42°C and the lowest minimum temperature observed during winter is around 9°C. The variation of mean monthly maximum, minimum and average temperatures at project site is shown in Figure - 6.1.

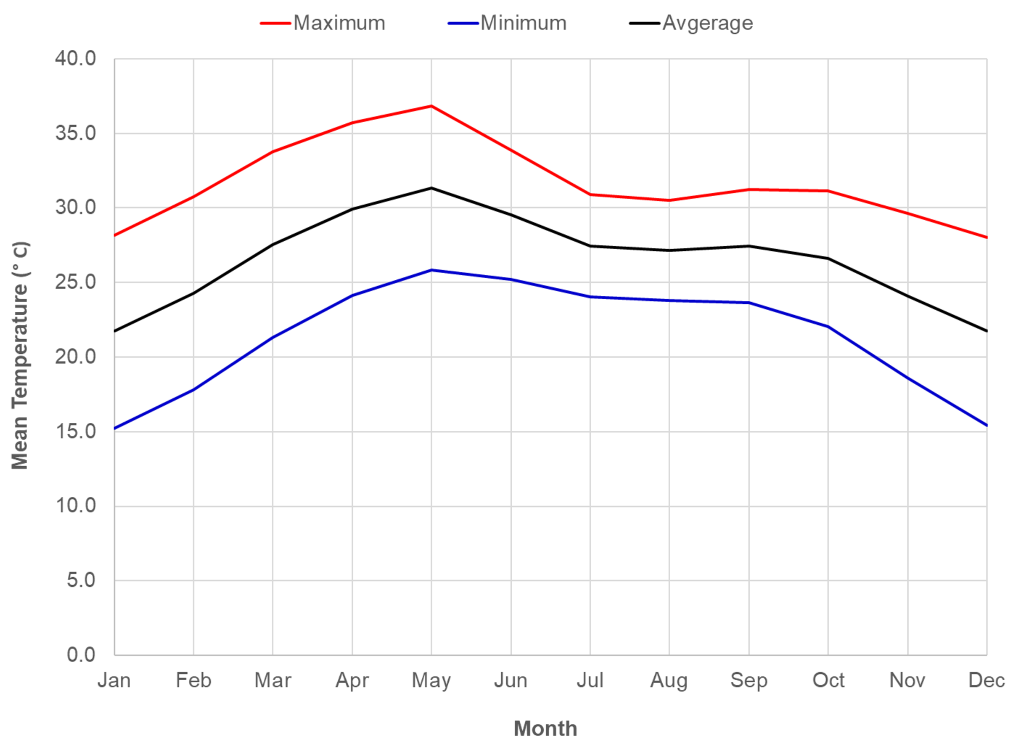


Figure - 6.1: Temperature Variation at Project Site

6.1.2 *Rainfall Data*

The daily gridded (0.25° x 0.25°) rainfall data of the project area has been obtained from Indian Meteorological Department for the recent 30 years period during January 1991 to December 2020. The weighted average monthly and annual rainfall for the overall catchment region of project has been estimated. The variation of annual rainfall and average monthly rainfall during the above period has been plotted and is shown in Figures - 6.2 and 6.3 respectively.

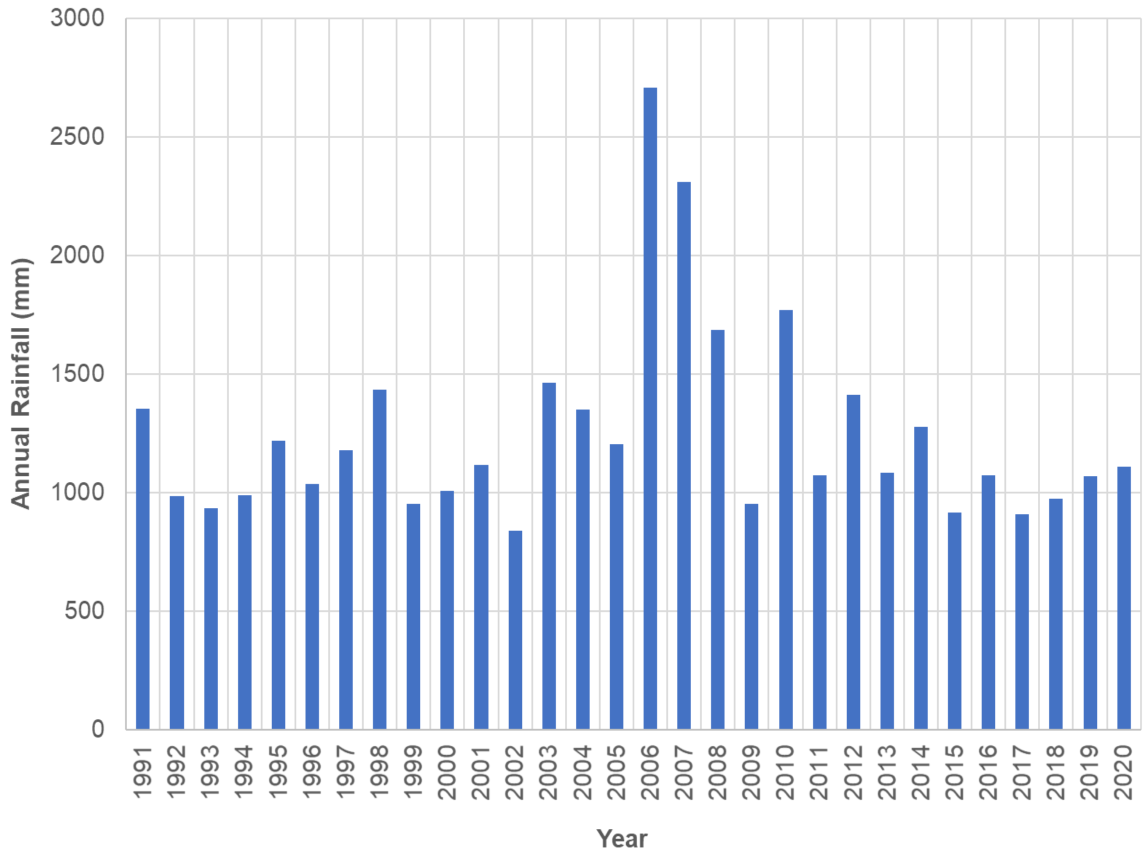


Figure - 6.2: Variation of Annual Rainfall

As seen from Figure - 6.2, the annual rainfall of both upper and lower dam catchment area varies from a maximum of 2708 mm during 2006 to a minimum of 839 mm during 2002, with an average annual rainfall of about 1247 mm.

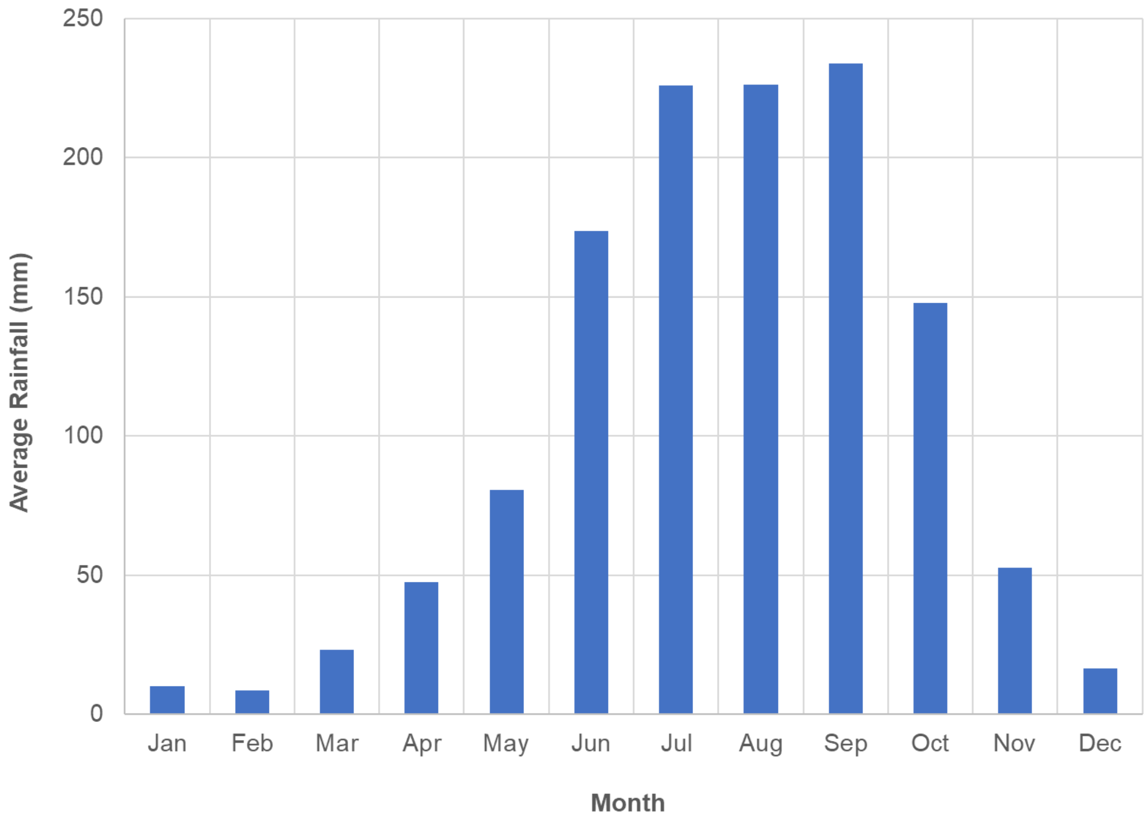


Figure - 6.3: Average Monthly Rainfall

As seen from Figure - 6.3, about 80% of total annual rainfall occurs during the monsoon months of June to October.

6.1.3 *Gauge Discharge Data*

Boduru Gedda and Suvarnamukhi river flows are currently not being gauged and hence there is no flow data available. In the absence of pertinent data, gauged flow data of nearby Gosthani river basin is considered for further studies. Gauged flows of Gosthani river at Kasipatnam station has been downloaded from India-WRIS website and the same has been used for estimation of monthly and annual yield at upper and lower dam sites. The catchment area of Gosthani river at Kasipatnam gauging station has been estimated to be about 225 km^2. The average monthly flows of of Gosthani River at Kasipatnam Gauging Station are furnished in Annexure - 6.1.

In addition to the above, a gauge discharge station has been established across Boduru Gedda river, about 6.3 km downstream of proposed lower dam site near Dandigam village. Gauge and discharge measurements will be carried out for a period of one (1) year continuously covering both monsoon and post-monsoon seasons, in line with the scope of work envisaged for the project.

Automatic discharge measurement option was adopted for the project owing to its advantages in obtaining continuous water level/flow data. Various options of automatic discharge measurement were examined to select the most suitable and reliable equipment / methodology for installation and monitoring of river gauge and discharges. Accordingly, **Nivuflow 750 transmitter** with ultrasonic wedge sensor, which operates based on cross correlation principle has been adopted.

Factory testing of sensor/equipment has been carried out by M/s. NIVUS GmbH at its factory in Germany in January 2021. Further, calibration of river discharge equipment and finalization of optimum location of sensor at gauging site has been completed in March 2021. Gauge (depth of flow), velocity and discharge observations are being recorded continuously and retrieved at hourly interval from 1800 hours on 10th Mar 2021.

The location of gauging site has been finalized based on the site conditions and technical requirements and is accordingly, established at an existing causeway / RCC box culvert across Boduru Gedda river near Dandigam village (Latitude: 18.6097° N and Longitude: 83.1120° E). The catchment area of river at gauging site has been estimated to be about 101.4 km^2. The average daily flows of Boduru Gedda river at Dandigam gauging station are furnished in Annexure - 6.2.

6.1.4 *Lake Evaporation*

The month-wise mean daily pan evaporation data of Visakhapatnam station, located about 110 km away from the project site has been considered for the present study. A pan-evaporation coefficient of 0.70 (as per IS 6939) has been considered to estimate the annual lake evaporation for the reservoirs.

6.1.5 *Sediment Inflows*

An average siltation rate of 759 m^3/km^2/year and a median siltation rate of 678 m^3/km^2/year has been recommended by Central Water Commission (CWC) for reservoirs located in Region - 3 (East flowing rivers upto Godavari excluding Ganga). Further, hydrographic survey carried out for three reservoirs, viz., Thandawa reservoir, Konam reservoir and Raiwada reservoirs located in Visakhapatnam district (*Sediment Yield Studies for Selected*

Catchments in Visakhapatnam District, Andhra Pradesh - J. Rangaiah.et al.Int. Journal of Engineering Research and Applications, Vol. 6, Issue 4, (Part - 5) April 2016,) located in Region - 3 resulted in the following sediment yields:

Table - 6.1: Observed Siltation Rates of Reservoirs

Sl. No.	Reservoir	Sediment Rate ($m^3/km^2/year$)
1	Thandawa	580
2	Konam	783
3	Raiwada	1368

Considering the above aspects, an average siltation rate of about 759 $m^3/km^2/year$ has been considered for the project. This will be further reviewed during DPR stage.

6.1.6 *Flood Inputs*

The design flood has been estimated by carrying out flood frequency analysis on the transposed flood peaks at dam sites. As both the dams are more than 30 m in height, PMF is considered as spillway design flood in accordance with IS 11223. Detailed flood studies using hydro-meteorological approach as per CWC guidelines will be carried out during DPR stage considering synthetic unit hydrograph relations applicable for Eastern Coast Region, i.e., Sub-zone 4 (a, b & c).

6.2 Effect of Project Development on Hydrologic Regime

6.2.1 *Effect on Low Flows*

The proposed Kurukutti PSP envisages recycling of stored water between upper and lower reservoirs and requires filling of reservoirs only once in its lifetime. Further, a small quantity of water will be used annually to recuperate the water lost due to evaporation and transit losses. The water requirement towards recuperation of losses will be done during monsoon season, when the flows are substantial. Hence, there will be no effect on low flows due to construction of project. Also, location of both the dams is within the initial reaches of river basin and hence, there will not be any substantial alteration of river flows.

6.2.2 *Effect on Peak Flood*

The flood absorption/moderation aspects of reservoirs will be reviewed during DPR stage. The flood absorption capacity in the reservoirs will be beneficial in moderating the floods downstream.

6.2.3 *Effect on Total Run-off*

The total loss due to evaporation and transit from upper and lower reservoirs is approximately about 2.4 Mm^3. As no consumptive use of water is envisaged beyond the recuperation of evaporation losses, total loss in run-off is not significant.

6.2.4 *Effect on Sediment Flow*

The ratio of annual sediment volume to gross capacity for upper and lower reservoirs is estimated to be about 0.03% and 0.16% respectively. The problem of siltation is generally considered insignificant if the ratio is less than 0.1% per year (Ref. IS: 12182). Detailed studies will be carried out for lower dam during DPR stage considering significantly high sediment volume entering the reservoir.

6.2.5 *Effect on Water Quality*

The proposed pumped storage scheme will not induce any changes in the water quality parameters in the upstream and downstream areas.

6.2.6 *Effect from Water demand*

Being a pumped storage scheme with only evaporation and transmission losses from upper and lower reservoirs, no major changes in water quantity and schedule of water demand in upstream and downstream areas are anticipated.

6.3 Hydrological Studies

6.3.1 *Water Availability Studies*

Monthly and annual yield at upper and lower dams has been estimated using gauged flows of Gosthani river by catchment area proportionality method. The details of calculations for estimation of average annual yield at upper and lower dams is furnished in Annexure - 6.3.

a) Upper Dam

The catchment area of minor nallah upto the proposed upper dam site has been estimated to be about 5 km^2. Gauged flows of Gosthani river at Kasipatnam station are available for the period during Jun 2000 to Jan 2012 (with a few missing data) and the same has been considered for estimation of average yield at dam site. The average annual yield at dam site has been estimated to be about 3.4 Mm^3. The variation of average monthly yield is shown in Figure - 6.4.

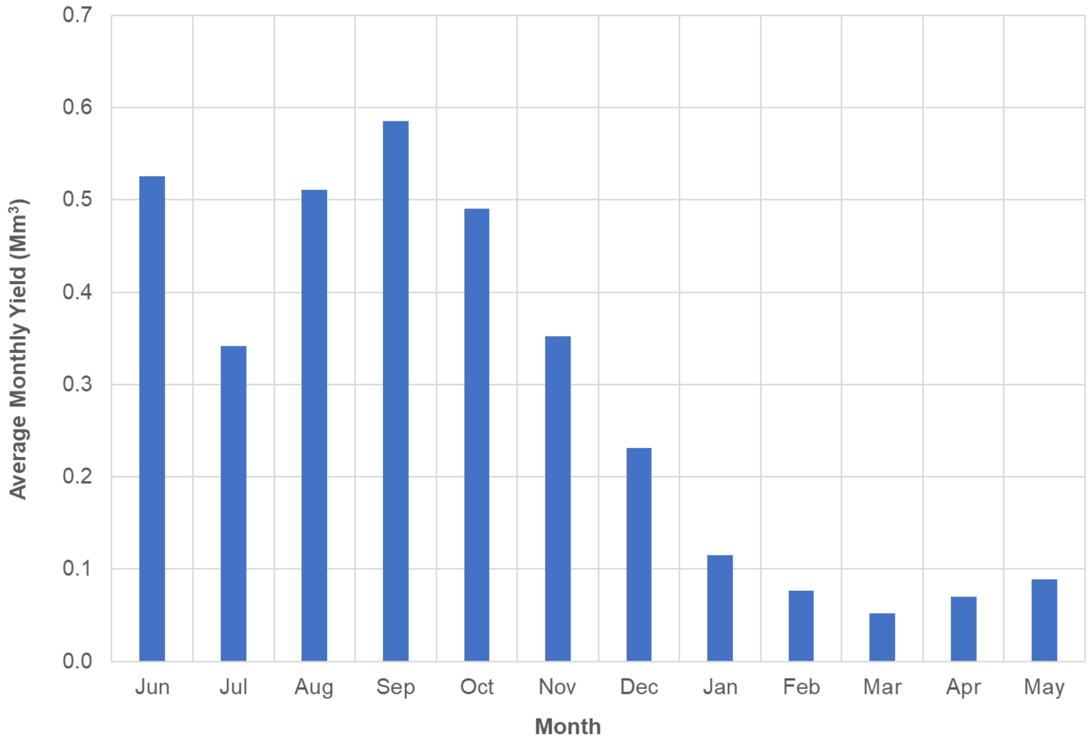


Figure - 6.4: Average Monthly Yield at Upper Dam Site

b) Lower Dam

The catchment area of Boduru Gedda river up to the proposed lower dam site has been estimated to be about 83.2 km^2. Average yield at lower dam site has been estimated using gauged flows of Gosthani river at Kasipatnam considering hydro-meteorologically similar characteristics of both the river basins. Accordingly, the average annual yield at lower dam site has been estimated to be about 57.2 Mm^3. Considering an average annual rainfall of 1247 mm, the rainfall-runoff coefficient works out to be about 0.55.

The variation of average monthly yield is shown in Figure - 6.5.

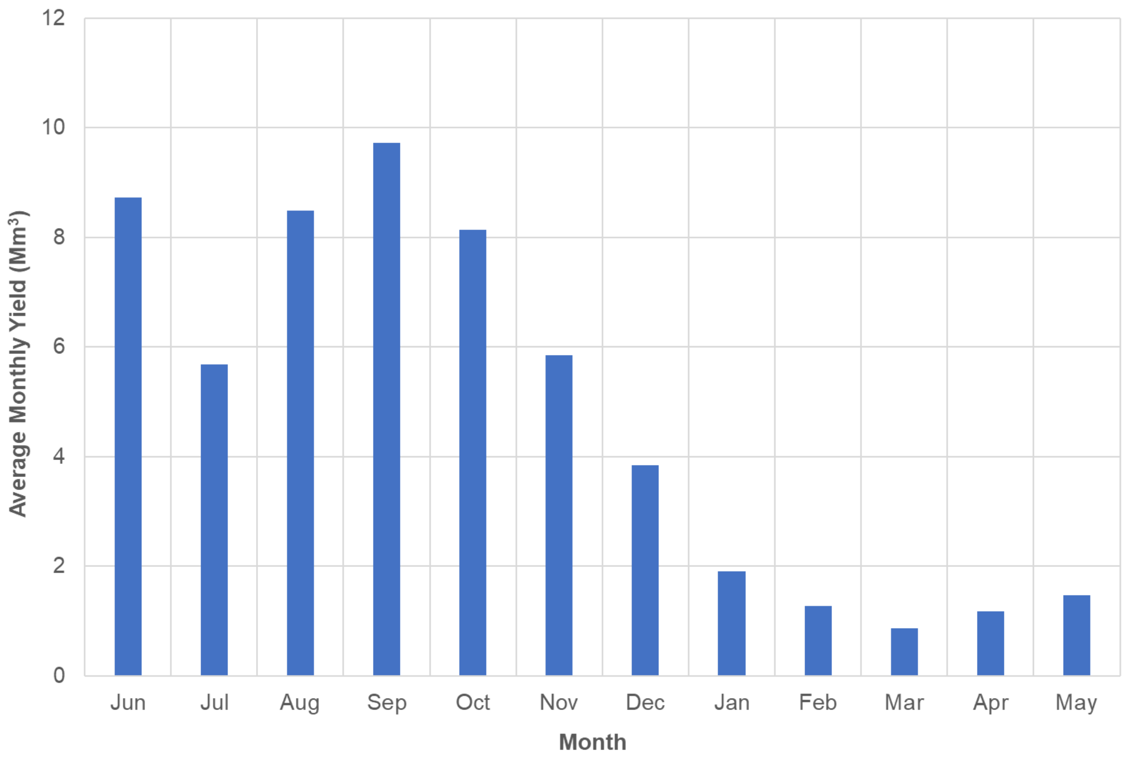


Figure - 6.5: Average Monthly Yield at Lower Dam Site

c) Observed Flows and Yield

As explained earlier, automatic gauge and discharge monitoring station has been established across Boduru Gedda river, near Dandigam village (about 6.3 km downstream of lower dam site). Hourly gauge, velocity and discharge data of river is available since 10^{th} March 2021 and the same has been considered for estimation of water availability at dam sites during the post-monsoon months of March (partly), April & May and monsoon months of June, July and August (partly). The summary of observed flows and yield at gauging site and estimated yield at upper and lower dam sites is furnished in Table - 6.2.

Table - 6.2: Summary of Observed Flows & Yield of Boduru Gedda River

Sl. No.	Description	Mar 2021 (10^{th} to 31^{st})	Apr 2021	May 2021	Jun 2021	Jul 2021	Aug 2021 (1^{st} to 9^{th})
1.	Observed Flows at Gauging Station (Dandigam), m^3/s	0.59	0.67	0.75	1.06	1.99	1.45
2.	Observed Yield at Gauging Station (Mm^3)	1.58*	1.73	2.01	2.75	5.34	3.89*
3.	Estimated Yield at Upper Dam Site (Mm^3)	0.08	0.09	0.10	0.14	0.26	0.19
4.	Estimated Yield at Lower Dam Site (Mm^3)	1.30	1.42	1.65	2.26	4.38	3.19

* - *extrapolated for full month based on average flows*

Upon comparison of yield estimates, it is found that estimated yield at project sites during the period from March to May is higher for Boduru Gedda river vis-à-vis yield estimated from Gosthani river basin. Considering the non-availability of long term flow data for Boduru Gedda river, yield estimated using Gosthani river flows is considered for the present study.

Long term yield estimates for upper and lower dam sites using observed flows of Boduru Gedda river will be carried out during DPR stage.

6.3.2 *Design Flood Studies*

a) Criteria for Design Flood Estimation

As per guidelines stipulated in IS: 11223:1985 (Guidelines for fixing the spillway capacity) the following criteria have been recommended considering the dam height and gross storage behind the dam and the criteria which gives the severe condition (height or storage) is adopted for fixing the criteria.

Table - 6.3: Design Flood Criteria for Spillway Design

Classification of Dam	Gross Storage (Mm^3)	Static head at FRL (m)	Design Flood criteria
Small	0.5 - 10.0	7.5 - 12.0	100 year flood
Intermediate	10.0 - 60.0	12.0 - 30.0	Standard Project Flood (SPF)
Large	> 60.0	> 30.0	Probable Maximum Flood (PMF).

The static head at FRL is greater than 30 m for both upper and lower dams. Hence, Probable Maximum Flood (PMF), which has a return period of 1 in 10,000 years has been considered as design flood.

b) Design Flood

Design flood corresponding to 10,000 year return period has been estimated based on flood frequency analysis. The peak annual flood discharges observed at Kasipatnam gauging station (Gosthani river) have been increased by 20% to account for the instantaneous flood peaks occurring in the river. The enhanced flood peaks have been transposed to respective dam sites and the flood discharges at different return periods have been estimated using Gumbel's distribution. The resulting flood discharges at upper and lower dam sites for various return periods is given in Table - 6.4 and the details of calculations are furnished in Annexure - 6.4.

Table - 6.4: Flood Discharges at Dam Sites

Return Period (Years)	Peak Flood (m^3/s)	
	Upper Dam	Lower Dam
10	28	185
25	39	252
100	54	352
500	72	467
1,000 (SPF)	79	516
10,000 (PMF)	104	680

As seen from the above table, design flood has been estimated to be about 104 m^3/s and 680 m^3/s for upper and lower dams respectively.

c) Comparison of Design Flood

For comparison, design flood is also estimated using various empirical formulae so as to verify the results as obtained from flood frequency analysis and the results are summarized in Table - 6.5.

Table - 6.5: Comparison of Design Flood (m^3/s)

Dam	Flood Frequency	Dicken's Formula	Ryve's Formula	Rational Formula
Upper	104	94	30	107
Lower	680	771	193	1783

In order to make a realistic assessment of the spillway flood discharge, comparison is made with the design flood discharge adopted for Pedda Gedda reservoir, located about 20 km from project site. Based on review of available data, it is found that the spillway of Pedda Gedda reservoir draining a total catchment area of about 216 km^2 has been designed for a peak flood of about 1400 m^3/s. However, Pedda Gedda reservoir being classified as an intermediate dam (static head in the range of 12 to 30 m and gross storage of about 30 Mm^3), would have been designed considering Standard Project Flood, which has a return period of 1 in 1000 years.

Thus, SPF at lower dam site has been estimated by transposing the design flood discharge of Pedda Gedda reservoir and has been found to be about 741 m^3/s, as against a flood discharge of 516 m^3/s estimated using Gumbel's method. The estimated flood discharges using Gumbel's method for various return periods has been re-computed using a correction factor of 1.44 (741 / 516 = 1.44). Accordingly, the design flood discharge of upper and lower dam works out to be about 150 m^3/s and 976 m^3/s for upper and lower dams respectively. Accordingly, the above flood discharges have been considered for design of spillway.

It is also suggested to carryout detailed flood studies during DPR stage in order to estimate design flood discharge corresponding to 1 in 10,000 year return period 24-hour rainfall using hydro-meteorological approach and synthetic unit hydrograph relations applicable for the project region. Design storm for the project region corresponding to 10,000 year return period (Probable Maximum Storm) shall be considered as about 315 mm, which corresponds to maximum 24-hour rainfall near Salur.

6.3.3 *Diversion Flood Studies*

The proposed project envisages construction of a 71 m high upper dam and 62 m high lower dam. Both dams will be of Roller Compacted Concrete dam (RCC) type and hence a flood of smaller return period can be considered sufficient for selecting the diversion flood. As per IS 14815, the following criteria are specified in deciding the capacity:

a) Maximum non-monsoon flow observed at the dam site

or

b) 25 years return period flow, calculated on the basis of non-monsoon yearly peaks

For the present study, 25 year return period monsoon flood is considered as diversion flood. Accordingly, diversion flood for upper and lower dam works out to be about 56 m^3/s and 362 m^3/s respectively, after applying the correction factor.

6.4 Sedimentation

Sedimentation studies for reservoirs is discussed in Chapter - VII (Reservoirs).

Annexure - 6.1

Average Monthly Flows (m^3/s) of Gosthani River at Kasipatnam Gauging Station

Month	2000-01	2001-02	2002-03	2003-04	2004-05	2005-06	2006-07	2007-08	2008-09	2009-10	2010-11	2011-12
Jun	6.25	2.56	5.01	2.97	5.02	2.40	2.35	40.70	9.98	-	12.33	2.57
Jul	2.23	2.05	-	2.99	10.14	1.27	0.85	3.65	15.61	1.61	14.55	3.06
Aug	7.09	6.26	2.40	4.86	4.68	2.72	9.07	2.77	23.47	2.36	23.85	5.07
Sep	8.41	4.37	3.35	6.21	4.14	11.44	3.13	26.37	11.05	2.22	24.45	6.76
Oct	9.00	14.67	5.37	15.75	3.36	11.86	1.05	20.78	2.02	3.50	2.27	1.08
Nov	4.36	8.69	1.16	6.17	2.47	8.12	1.10	0.09	-	1.95	26.88	0.72
Dec	0.81	3.39	0.87	8.14	1.63	2.25	1.49	-	-	-	12.79	0.72
Jan	2.21	2.36	0.67	4.85	1.12	0.74	0.46	-	-	-	3.21	0.29
Feb	1.21	1.53	0.41	3.60	0.68	0.19	0.09	-	-	-	2.78	-
Mar	-	0.92	0.49	2.13	0.21	0.20	0.04	0.93	-	-	1.53	-
Apr	1.88	1.27	0.55	3.08	0.36	0.11	0.02	-	-	-	1.72	-
May	0.76	0.68	-	2.23	0.55	1.57	1.41	0.24	-	2.11	2.76	-

Annexure - 6.2

Average Daily Flows (m^3/s) of Boduru Gedda River at Dandigam Gauging Station

Date	Avg. Discharge (m^3/s)
10-Mar-21	0.63
11-Mar-21	0.60
12-Mar-21	0.57
13-Mar-21	0.56
14-Mar-21	0.50
15-Mar-21	0.46
16-Mar-21	0.52
17-Mar-21	0.52
18-Mar-21	0.58
19-Mar-21	0.60
20-Mar-21	0.60
21-Mar-21	0.60
22-Mar-21	0.61
23-Mar-21	0.62
24-Mar-21	0.62
25-Mar-21	0.63
26-Mar-21	0.68
27-Mar-21	0.70
28-Mar-21	0.73
29-Mar-21	0.63
30-Mar-21	0.53
31-Mar-21	0.50
01-Apr-21	0.47
02-Apr-21	0.46
03-Apr-21	0.52
04-Apr-21	0.95
05-Apr-21	0.79
06-Apr-21	0.69
07-Apr-21	0.65
08-Apr-21	0.59
09-Apr-21	0.57
10-Apr-21	0.61
11-Apr-21	0.65
12-Apr-21	0.65
13-Apr-21	0.67
14-Apr-21	0.67
15-Apr-21	0.75
16-Apr-21	0.72
17-Apr-21	0.75
18-Apr-21	0.61
19-Apr-21	0.49
20-Apr-21	0.55
21-Apr-21	0.64
22-Apr-21	0.69

Date	Avg. Discharge (m^3/s)
23-Apr-21	0.67
24-Apr-21	0.67
25-Apr-21	0.60
26-Apr-21	0.62
27-Apr-21	0.90
28-Apr-21	0.81
29-Apr-21	0.74
30-Apr-21	0.88
01-May-21	0.73
02-May-21	0.66
03-May-21	0.69
04-May-21	0.80
05-May-21	0.93
06-May-21	0.80
07-May-21	0.77
08-May-21	0.88
09-May-21	0.91
10-May-21	1.09
11-May-21	1.07
12-May-21	1.40
13-May-21	0.92
14-May-21	0.86
15-May-21	1.14
16-May-21	0.74
17-May-21	0.68
18-May-21	0.58
19-May-21	0.47
20-May-21	0.47
21-May-21	0.73
22-May-21	0.76
23-May-21	0.83
24-May-21	0.63
25-May-21	0.59
26-May-21	0.51
27-May-21	0.53
28-May-21	0.51
29-May-21	0.51
30-May-21	0.55
31-May-21	0.51
01-Jun-21	1.83
02-Jun-21	0.97
03-Jun-21	1.21
04-Jun-21	1.64
05-Jun-21	1.84
06-Jun-21	1.89
07-Jun-21	1.77
08-Jun-21	1.30
09-Jun-21	1.05
10-Jun-21	1.10
11-Jun-21	1.40

Date	Avg. Discharge (m^3/s)
12-Jun-21	1.23
13-Jun-21	0.99
14-Jun-21	1.07
15-Jun-21	1.00
16-Jun-21	0.83
17-Jun-21	0.93
18-Jun-21	0.96
19-Jun-21	0.91
20-Jun-21	0.84
21-Jun-21	0.75
22-Jun-21	0.69
23-Jun-21	0.63
24-Jun-21	0.58
25-Jun-21	0.58
26-Jun-21	0.58
27-Jun-21	0.87
28-Jun-21	1.05
29-Jun-21	0.74
30-Jun-21	0.66
01-Jul-21	0.66
02-Jul-21	0.69
03-Jul-21	0.67
04-Jul-21	0.68
05-Jul-21	0.76
06-Jul-21	0.62
07-Jul-21	0.58
08-Jul-21	0.54
09-Jul-21	0.53
10-Jul-21	0.64
11-Jul-21	1.15
12-Jul-21	2.80
13-Jul-21	7.29
14-Jul-21	5.24
15-Jul-21	5.41
16-Jul-21	3.60
17-Jul-21	2.55
18-Jul-21	2.08
19-Jul-21	2.18
20-Jul-21	1.95
21-Jul-21	2.42
22-Jul-21	2.17
23-Jul-21	2.33
24-Jul-21	1.84
25-Jul-21	1.52
26-Jul-21	1.28
27-Jul-21	1.12
28-Jul-21	1.10
29-Jul-21	2.52
30-Jul-21	2.67
31-Jul-21	2.16

Date	Avg. Discharge (m^3/s)
01-Aug-21	2.12
02-Aug-21	1.86
03-Aug-21	1.83
04-Aug-21	1.58
05-Aug-21	1.39
06-Aug-21	1.34
07-Aug-21	1.12
08-Aug-21	0.99
09-Aug-21	0.85

Annexure - 6.3

Estimation of Average Annual Yield

at Upper and Lower Dams

1. Basic Data:

a) Catchment Area of:

- Gosthani river at Kasipatnam gauging station = 225.5 km^2
- Boduru Gedda river at Upper dam site = 5.0 km^2
- Boduru Gedda river at Lower dam site = 83.2 km^2

b) Weighted Average Annual Rainfall for:

- Catchment upto Kasipatnam gauging station = 1144 mm
- Catchment upto upper dam site = 1247 mm
- Catchment upto lower dam site = 1247 mm

2. Average Monthly Flows & Yield at a Kasipatnam Station

Month	Average Flow, (m^3/s)	Days	Yield (Mm^3)
Jun	8.4	30	21.7
Jul	5.3	31	14.1
Aug	7.9	31	21.1
Sep	9.3	30	24.2
Oct	7.6	31	20.2
Nov	5.6	30	14.5
Dec	3.6	31	9.6
Jan	1.8	31	4.7
Feb	1.3	28	3.2
Mar	0.8	31	2.2
Apr	1.1	30	2.9
May	1.4	31	3.7
		Total	**142.1**

3. Estimation of Average Monthly Yield at Upper & Lower Dam Sites

Typical computations for estimation of average yield for the month of Jun

a) <u>Upper Dam</u>

Average monthly yield = 21.7 x (5 / 225.5) x (1247 / 1144)

= 0.5 Mm^3

b) Lower Dam

Average monthly yield = 21.7 x (83.2 / 225.5) x (1247 / 1144)

= 8.7 Mm^3

Similar computations have been carried out for other months and the results are summarized in the Table given below:

Month	**Average Yield (Mm^3)**	
	Upper Dam	**Lower Dam**
Jun	0.5	8.7
Jul	0.3	5.7
Aug	0.5	8.5
Sep	0.6	9.7
Oct	0.5	8.1
Nov	0.4	5.8
Dec	0.2	3.8
Jan	0.1	1.9
Feb	0.1	1.3
Mar	0.1	0.9
Apr	0.1	1.2
May	0.1	1.5
Total	**3.4**	**57.2**

Annexure - 6.4
Estimation of Design Flood for Upper and Lower Dams

1. Basic Data:

a) Catchment Area of:

- Gosthani river at Kasipatnam gauging station = 225.5 km^2
- Boduru Gedda river at Upper dam site = 5.0 km^2
- Boduru Gedda river at Lower dam site = 83.2 km^2

2. Peak Annual Flood Discharges at Kasipatnam

Observed peak floods of Gosthani river at Kasipatnam gauging station have been enhanced by 20% to account for instantaneous flood peaks.

Year	Peak Annual Flood (m^3/s)	
	Observed	**Instantaneous**
2000-01	42	50
2001-02	30	36
2002-03	36	43
2003-04	82	99
2004-05	59	71
2005-06	72	87
2006-07	148	178
2007-08	427	513
2008-09	54	65
2009-10	21	26
2010-11	166	199
2011-12	37	44
Average	**98**	**117**
Std. Dev.	**113**	**136**

3. Peak Annual Flood Discharges at Upper and Lower Dams

Transposed peak flood discharges at upper and lower dam sites have been calculated using the following equation:

<u>Typical computations</u>

Peak flood at upper dam site $= 50 \times (5.0 / 225.5)^{2/3}$

$= 4\ m^3/s$

Peak flood at lower dam site $= 50 \times (83.2 / 225.5)^{2/3}$

$= 26\ m^3/s$

Peak annual flood discharges for upper and lower dams has been calculated for all the 12 years period and results are tabulated below:

Year	Peak Annual Flood (m^3/s)	
	Upper Dam	**Lower Dam**
2000-01	4	26
2001-02	3	18
2002-03	3	22
2003-04	8	51
2004-05	6	37
2005-06	7	45
2006-07	14	91
2007-08	41	264
2008-09	5	33
2009-10	2	13
2010-11	16	103
2011-12	4	23
Average	**9**	**60**
Std. Dev.	**11**	**70**

4. Flood Frequency Analysis

Gumbel's (Extreme Value Distribution) method has been used for estimation of peak flood discharges corresponding to various return periods using Method of Moments

a) Sample Size, N = 12 years

b) Reduced Mean, Y_n = 0.5035

c) Reduced Std. Deviation, S_n = 0.9833

d) Peak flood, Q_T = $Q_{avg.} + K*\sigma$

e) Frequency factor, K = $(Y_T - Y_n)/S_n$

f) Y_T = - [ln*ln (T/T-1)]

Peak flood for various Return Periods for upper and lower dams is tabulated below:

Return Period (Years)	Reduced Variate (Y_T)	Frequency Factor (K)	Peak Flood (m^3/s)	
			Upper Dam	**Lower Dam**
5	1.500	1.013	20	131
10	2.250	1.777	28	185
25	3.199	2.741	39	252
100	4.600	4.166	54	352
500	6.214	5.807	72	467
1000 (SPF)	6.907	6.513	79	516

Return Period (Years)	Reduced Variate (Y_T)	Frequency Factor (K)	Peak Flood (m^3/s)	
			Upper Dam	Lower Dam
10000 (PMF)	9.210	8.855	104	680

5. Peak Flood Discharges using Empirical Formulae

a) Dickens Formula, Qp = C x $A^{3/4}$

C - Dickens coefficient (C = 28)

A - Catchment area (A = 5.0 km^2 for upper dam & 83.2 km^2 for lower dam)

Peak flood, Qp = 94 m^3/s (Upper dam)

=771 m^3/s (Lower dam)

b) Ryve's Formula, Qp = C x $A^{2/3}$

C - Ryve's coefficient = 10.1

A - Catchment area (A = 5.0 km^2 for upper dam & 83.2 km^2 for lower dam)

Peak flood, Qp = 30 m^3/s (Upper dam)

=193 m^3/s (Lower dam)

c) Rational Formula, Qp = C x I x A

C - Runoff coefficient (C = 0.55)

I - Design rainfall intensity (I = 140 mm/hour, estimated from 24 hour PMP value of 315 mm applicable for project region)

A - Catchment Area

Peak flood, Qp = 107 m^3/s (Upper dam)

= 1783 m^3/s (Lower dam)

6. Corrected Peak Flood Discharges

The design peak corresponding to 10,000 year return period for both upper and lower dams has been estimated based on limited data of 12 years available for Gosthani river, which is flowing adjacent to the project catchment area. In order to assess the accuracy of the estimated flood discharges, comparison has been made against the design peak flood adopted for Pedda Gedda reservoir, located about 20 km from project site.

Catchment area of river upto Pedda Gedda reservoir = 216 km^2

Design peak flood (SPF, 1 in 1000 year return period) = 1400 m^3/s.

Transposed peak flood at lower dam site = 1400 x $(83.2 / 216)^{2/3}$

=741 m^3/s

Thus, transposed peak flood at lower dam corresponding to 1000 year return period has been found to be about 44% higher than the flood discharge estimated from flood frequency analysis. Pending detailed studies, the flood discharges estimated using flood frequency method has been enhanced by 44% and the resulting corrected peak flood discharges for upper and lower dams for various return periods is given below:

Return Period (Years)	Peak Flood (m^3/s)	
	Upper Dam	Lower Dam
5	29	189
10	41	265
25	56	362
100	78	505
500	103	670
1000 (SPF)	114	741
10000 (PMF)	150	976

Chapter - VII
Reservoirs

7.1 Reservoir Characteristics and Run-off Studies

7.1.1 *Catchment Area*

The catchment area of proposed upper dam site near Chemidipatipolam village lies between Longitude 83° 01’ 02” E to 83° 03’ 11” E & Latitude 18° 36’ 34” N to 18° 38’ 06” N. The catchment area of proposed lower dam site near Kurukutti village lies between Longitude 82° 57’ 35” E to 83° 05’ 30” E and Latitude 18° 32’ 06” N to 18° 39’ 35” N.

The catchment area of upper dam is estimated to be about 5 km^2 and catchment area of lower dam is about 83.2 km^2.

7.1.2 *Annual Runoff/ Reservoir Yield*

The estimation of catchment yield upto dam sites has been discussed in detail in Chapter - VI (Hydrology) of this report. The average annual yield at upper and lower dam sites has been estimated to be about 3.4 Mm^3 and 57.2 Mm^3 respectively.

7.1.3 *Dependability Studies*

A dependability analysis was carried out by performing ranking studies on the estimated annual yield. The 50%, 75% and 90% dependable yield estimated at proposed dam sites is furnished in Table - 7.1.

Table - 7.1: Annual Yield (Mm^3) at Dam Sites

Dependability	Upper Dam	Lower Dam
90 %	1.4	22.5
75 %	1.7	28.6
50 %	2.7	45.4

The details of calculations made for estimation of dependable yield at upper and lower dam sites is given in Annexure - 7.1.

7.2 Sedimentation Data and Studies

7.2.1 *Elevation-Area-Capacity Data of Reservoirs*

Elevation-Area-Capacity details of proposed reservoirs have been worked out from the contour maps prepared for the project area. The area enclosed between successive contours is calculated and the volume between any two elevations is calculated using the following formula:

$$V = H/3*[A_1 + A_2 + \sqrt{A1*A2}\,]$$

Where V = Volume between two contours (Mm^3);
H = Contour interval/ Difference in elevation (m);
A_1 = Water spread area at first contour level (Mm^2); and
A_2 = Water spread area at second contour level (Mm^2)

The incremental volume of the reservoir between two contours thus obtained is summed up to estimate gross storage capacity of reservoir at different elevations.

a) Upper Reservoir

The water spread area and estimated gross storage capacity of upper reservoir at various elevations is furnished in Table - 7.2. It is observed that, gross capacity of the reservoir is about 12.6 Mm^3 at the proposed FRL of RL 899.00 m.

Table - 7.2: Elevation-Area-Capacity Data of Upper Reservoir

Elevation (RL in m)	Area (Mm^2)	Incremental Capacity (Mm^3)	Gross Storage Capacity (Mm^3)	Remarks
833.0	0.00030	-	0.0	
834.0	0.00090	0.0	0.0	
835.0	0.00230	0.0	0.0	
836.0	0.00460	0.0	0.0	
837.0	0.00680	0.0	0.0	
838.0	0.00960	0.0	0.0	
839.0	0.01180	0.0	0.0	
840.0	0.01290	0.0	0.0	
841.0	0.01570	0.0	0.1	
842.0	0.01700	0.0	0.1	
843.0	**0.01990**	**0.0**	**0.1**	**NZE**
844.0	0.02190	0.0	0.1	
845.0	0.02550	0.0	0.1	

Elevation (RL in m)	Area (Mm^2)	Incremental Capacity (Mm^3)	Gross Storage Capacity (Mm^3)	Remarks
846.0	0.02790	0.0	0.2	
847.0	0.03160	0.0	0.2	
848.0	0.03370	0.0	0.2	
849.0	0.03700	0.0	0.3	
850.0	0.03920	0.0	0.3	
851.0	0.04220	0.0	0.3	
852.0	0.04550	0.0	0.4	
853.0	0.04780	0.0	0.4	
854.0	0.05180	0.0	0.5	
855.0	0.05450	0.1	0.5	
856.0	0.05800	0.1	0.6	
857.0	0.06110	0.1	0.6	
858.0	0.06470	0.1	0.7	
859.0	0.06800	0.1	0.8	
860.0	0.07240	0.1	0.8	
861.0	**0.08100**	**0.1**	**0.9**	**MDDL**
862.0	0.09030	0.1	1.0	
863.0	0.10170	0.1	1.1	
864.0	0.11250	0.1	1.2	
865.0	0.12140	0.1	1.3	
866.0	0.13030	0.1	1.5	
867.0	0.14080	0.1	1.6	
868.0	0.15200	0.1	1.7	
869.0	0.16180	0.2	1.9	
870.0	0.17450	0.2	2.1	
871.0	0.18520	0.2	2.2	
872.0	0.19660	0.2	2.4	
873.0	0.20960	0.2	2.6	
874.0	0.21990	0.2	2.9	
875.0	0.23110	0.2	3.1	
876.0	0.24300	0.2	3.3	
877.0	0.25450	0.2	3.6	
878.0	0.26630	0.3	3.8	
879.0	0.28000	0.3	4.1	
880.0	0.29110	0.3	4.4	
881.0	0.30400	0.3	4.7	
882.0	0.31790	0.3	5.0	
883.0	0.33170	0.3	5.3	
884.0	0.34610	0.3	5.7	
885.0	0.36220	0.4	6.0	
886.0	0.37980	0.4	6.4	
887.0	0.39560	0.4	6.8	
888.0	0.41240	0.4	7.2	
889.0	0.42780	0.4	7.6	
890.0	0.44300	0.4	8.0	
891.0	0.45920	0.5	8.5	
892.0	0.47460	0.5	8.9	
893.0	0.48930	0.5	9.4	

Elevation (RL in m)	Area (Mm^2)	Incremental Capacity (Mm^3)	Gross Storage Capacity (Mm^3)	Remarks
894.0	0.50440	0.5	9.9	
895.0	0.51920	0.5	10.4	
896.0	0.53450	0.5	11.0	
897.0	0.54880	0.5	11.5	
898.0	0.56410	0.6	12.1	
899.0	**0.58030**	**0.6**	**12.6**	**FRL**
900.0	0.59400	0.6	13.2	
901.0	0.60970	0.6	13.8	
902.0	0.62650	0.6	14.4	
903.0	0.64300	0.6	15.1	
904.0	0.65910	0.7	15.7	
905.0	0.67720	0.7	16.4	

b) Lower Reservoir

The water spread area and estimated gross storage capacity of lower reservoir at various elevations is furnished in Table - 7.3. It is observed that, gross capacity of the reservoir is about 38.7 Mm^3 at the proposed FRL of RL 306.00 m.

Table - 7.3: Elevation-Area-Capacity Data of Lower Reservoir

Elevation (RL in m)	Area (Mm^2)	Incremental Capacity (Mm^3)	Gross Storage Capacity (Mm^3)	Remarks
249.0	0.00150	-	0.0	
250.0	0.00720	0.0	0.0	
251.0	0.01440	0.0	0.0	
252.0	0.02160	0.0	0.0	
253.0	0.03040	0.0	0.1	
254.0	0.04000	0.0	0.1	
255.0	0.04990	0.0	0.1	
256.0	0.06380	0.1	0.2	
257.0	0.07970	0.1	0.3	
258.0	0.09810	0.1	0.4	
259.0	0.11390	0.1	0.5	
260.0	0.13020	0.1	0.6	
261.0	0.14690	0.1	0.7	
262.0	0.16470	0.2	0.9	
263.0	0.18340	0.2	1.1	
264.0	0.20240	0.2	1.2	
265.0	**0.22730**	**0.2**	**1.5**	**NZE**
266.0	0.25550	0.2	1.7	
267.0	0.28680	0.3	2.0	
268.0	0.31970	0.3	2.3	
269.0	0.35510	0.3	2.6	

Elevation (RL in m)	Area (Mm^2)	Incremental Capacity (Mm^3)	Gross Storage Capacity (Mm^3)	Remarks
270.0	0.39320	0.4	3.0	
271.0	0.43010	0.4	3.4	
272.0	0.46820	0.4	3.8	
273.0	0.50420	0.5	4.3	
274.0	0.53570	0.5	4.9	
275.0	0.56760	0.6	5.4	
276.0	0.60030	0.6	6.0	
277.0	0.63070	0.6	6.6	
278.0	0.66360	0.6	7.2	
279.0	0.69560	0.7	7.9	
280.0	0.72810	0.7	8.6	
281.0	**0.76110**	**0.7**	**9.4**	**MDDL**
282.0	0.79310	0.8	10.2	
283.0	0.82480	0.8	11.0	
284.0	0.85540	0.8	11.8	
285.0	0.88580	0.9	12.7	
286.0	0.91550	0.9	13.6	
287.0	0.94710	0.9	14.5	
288.0	0.97800	1.0	15.5	
289.0	1.01050	1.0	16.5	
290.0	1.04480	1.0	17.5	
291.0	1.08080	1.1	18.6	
292.0	1.11470	1.1	19.7	
293.0	1.14830	1.1	20.8	
294.0	1.18650	1.2	22.0	
295.0	1.22220	1.2	23.2	
296.0	1.25790	1.2	24.4	
297.0	1.29320	1.3	25.7	
298.0	1.32750	1.3	27.0	
299.0	1.36240	1.3	28.3	
300.0	1.39460	1.4	29.7	
301.0	1.42670	1.4	31.1	
302.0	1.46080	1.4	32.6	
303.0	1.49370	1.5	34.0	
304.0	1.52710	1.5	35.6	
305.0	1.56070	1.5	37.1	
306.0	**1.59230**	**1.6**	**38.7**	**FRL**
307.0	1.62560	1.6	40.3	
308.0	1.66100	1.6	41.9	
309.0	1.69270	1.7	43.6	
310.0	1.72570	1.7	45.3	

7.2.2 *Design Requirement*

As per IS:12182, Guidelines for Determination of Effects of Sedimentation in Planning & Performance of Reservoirs, the revised reservoir capacity after a period of 25 years needs to be estimated. Similarly, at the design stage it is essential to predict the extent of sediment deposition at or near the hydraulic structure in order to fix the outlet/sill levels after a time horizon of 25 & 70 years. The above aspects have been included in the sedimentation study.

7.2.3 *Sediment Data*

As explained earlier, an average sediment load of 759 m^3/km^2/year has been considered for assessing the effect of sedimentation on storage capacity of reservoirs considering a design/serviceable life of 100 years. However, it is suggested to carry out a few samples of siltation rates of the river/nallah at dam sites during DPR stage for detailed planning of reservoirs.

7.2.4 *Classification of Sedimentation Problem*

As per IS : 12182, Guidelines for Determination of Effects of Sedimentation in Planning & Performance of Reservoirs, if the ratio of annual silt load to the gross storage capacity of reservoir is less than 0.1 % per year, the problem of siltation may be considered insignificant and changes in reservoir capacity can be neglected for studies of reservoir performance.

a) Upper Reservoir

The annual sediment load for upper reservoir considering a catchment area of 5 km^2 works out to 3795 m^3. The ratio of average annual sediment volume to gross capacity works out to be 0.03%.

b) Lower Reservoir

The annual sediment load for lower reservoir considering a catchment area of about 83.2 km^2 works out to be about 63,149 m^3. The ratio of average annual sediment volume to gross capacity works out to be 0.16%. Detailed studies are required to be carried out during DPR stage for assessing the changes in reservoir capacity over its serviceable life of 100 years.

c) Prediction of Sedimentation Distribution

The sediment entering storage reservoir gets deposited progressively with the passage of time and thereby reduces the dead as well as live storage capacity of the reservoir. This causes the bed level near the dam to rise and the raised bed level is termed as new zero elevation. For the sake of present study, New Zero Elevation (NZE) of reservoirs has been considered as the elevation of reservoir corresponding to 20% of total sediment entering the reservoir for a serviceable life of 100 years. The resulting NZE considered for the present study is given below:

- $NZE_{100\ years}$ for Upper Dam - RL 843.00 m
- $NZE_{100\ years}$ for Lower Dam - RL 265.00 m

The above considered NZE for both upper and lower dams has been found to be higher than the value of new zero elevation established using Area Increment method. Hence, the above values have been considered for the present study pending further review during DPR stage. Detailed studies will be made using Empirical Area Reduction method, as per IS 5477_Part 2 to establish the New Zero Elevation of reservoirs.

7.3 Fixation of Storage and Reservoir Levels

7.3.1 *General*

The storage planning for weekly cycle of operation for proposed Kurukutti pumped storage project envisages:

- Generation - 7 hours a day during 6 days in a week.
- Pumping - 7 hours every day and pumping all the remaining water on Sunday.

The net storage requirement for the project considering weekly cycle operation has been estimated and found to be about 11.0 Mm^3.

7.3.2 *Lower Reservoir Storage Capacity*

The gross storage capacity required for lower reservoir is estimated as below:

Table - 7.4: Storage Capacity of Lower Dam

Sl. No.	Description	Storage (Mm^3)
1	Gross storage at MDDL (RL 281.00)	9.4
2	Storage requirement based on weekly cycle operation (Kurukutti PSP)	11.0
3	Storage requirement based on weekly cycle operation (Karrivalasa PSP)	11.1

Sl. No.	Description	Storage (Mm^3)
4	Evaporation loss estimated at Upper reservoir (Kurukutti PSP & Karrivalasa PSP)	0.9
5	Transit losses at 5% of evaporation losses of upper res.	0.0
6	Evaporation loss estimated at lower reservoir	1.9
7	Transit losses at 5% of evaporation losses of lower res.	0.1
8	Loss of live storage due to sedimentation (lower res.)	3.2
	Total	**37.6**

The gross storage capacity available at RL 306.00 m is estimated as 38.7 Mm^3, which is considered as FRL.

7.3.3 *Upper Reservoir Storage Capacity*

The gross storage capacity required for upper reservoir is estimated as below:

Table - 7.5: Storage Capacity of Upper Dam

Sl. No.	Description	Storage (Mm^3)
1	Gross Storage at MDDL (RL 861.00)	0.9
2	Storage requirement based on weekly cycle operation	11.0
3	Loss of live storage due to sedimentation (upper)	0.2
	Total	**12.1**

The gross storage capacity available at RL 899.00 m is estimated at 12.6 Mm^3, which is considered as FRL.

7.3.4 *Fixation of Reservoir Levels*

a) Minimum Draw Down Level (MDDL)

The MDDL of both upper and lower reservoirs has been fixed based on the considerations of New Zero Elevation after 100 years of reservoir life and the minimum submergence criteria required for intakes. The minimum submergence required for the intake has been verified as per Gordon's formula and IS 9761 (*Hydro Power Intakes - Criteria for Hydraulic Design*). The details of calculations made for estimation of minimum submergence required at upper and lower intakes is given in Annexure - 7.2.

The top of bell-mouth intake has been kept 2 m above the estimated NZE and considering the submergence requirement above the top of bell-mouth intake. Accordingly, MDDL of upper and lower dams are fixed at RL 861.00 m and RL 281.00 m respectively.

b) Full Reservoir Level (FRL)

The full reservoir level of reservoirs has been fixed considering the storage requirement necessary for reliable operation of the proposed pumped storage project considering weekly regulation and other criteria. Accordingly, the FRL of upper and lower dams has been fixed at RL 899.00 m and RL 306.00 m respectively.

c) Maximum Water Level (MWL)

The maximum water level in the reservoirs has been estimated considering the design flood discharge and head over the un-gated/gated ogee spillway. The maximum water levels in upper and lower reservoirs has been estimated to be about RL 900.80 m and RL 307.90 m respectively and details of calculations are furnished in Annexure - 7.3.

The effect of reduction in outflow flood discharge due to reservoir storage has not been considered in the present study. However, flood routing studies using Modified Pul's method will be carried out during DPR stage.

7.4 Life of Reservoir

As per *IS: 12182-1987, Guidelines for Determination of Effects of Sedimentation in Planning & Performance of Reservoirs*, the feasible service time for hydro power projects supplying power to a grid shall not be less than 70 years. Accordingly, the life of both the upper and lower reservoirs has been considered as 100 years for the proposed pumped storage project.

7.5 Annual Losses

7.5.1 *Lake Evaporation Losses*

The mean daily pan evaporation of Visakhapatnam station has been considered for estimation of lake evaporation losses in the reservoirs. A pan coefficient of 0.7 has been adopted to determine the mean daily/monthly lake evaporation rates as shown below:

Table - 7.6: Mean Monthly Evaporation Rate

Month	Mean Daily Pan Evaporation (mm/day)	Mean Lake Evaporation (mm/day)	No. of Days	Lake Evaporation (mm)
Jan	5.5	3.85	31	119
Feb	6.5	4.55	28	127
Mar	7.7	5.39	31	167
Apr	8.8	6.16	30	185
May	9.2	6.44	31	200
Jun	3.0	2.10	30	63
Jul	6.1	4.27	31	132
Aug	6.0	4.20	31	130
Sep	5.2	3.64	30	109
Oct	5.1	3.57	31	111
Nov	5.8	4.06	30	122
Dec	5.6	3.92	31	122
			TOTAL	**1587**

Say 1.6 m

With the above evaporation rate, the annual lake losses has been calculated for both reservoirs and is furnished in Table - 7.7 and details of calculations are furnished in Annexure - 7.4.

Table - 7.7: Evaporation Losses at Reservoirs

Reservoir	Mean Water Spread Area (Mm^2)	Annual Evaporation Loss (Mm^3)
Upper	0.2927	0.5
Lower	1.1514	1.9

As explained earlier, the compensatory storage to account for evaporation and transit losses in upper reservoir has been accommodated in lower reservoir itself.

7.6 Submergence Area

Based on available topographical data, the water spread area of upper and lower reservoirs has been found to be about 58 Hectares at FRL of RL 899.00 m and about 160 Hectares at FRL of RL 306.00 m respectively.

7.7 Land Acquisition

The construction of upper and lower dam will result in submergence of land which has to be acquired from concerned agencies like forest department, private parties etc. The area of land to be acquired for upper and lower reservoirs is tabulated below.

Table - 7.8: Land Details for Reservoirs

Sl. No.	Reservoir	Total Land (Ha)	Forest Land (Ha)	Govt./ Private Land (Ha)
1	Upper	58	-	58
2	Lower	160	50	110

Annexure - 7.1
Estimation of Dependable Yield
at Upper and Lower Dam Sites

A. Annual Yield of Gosthani River

Annual yield of Gosthani river (Mm^3) at Kasipatnam gauging station has been estimated and the results are given below:

Month	2000-01	2001-02	2002-03	2003-04	2004-05	2005-06	2006-07	2007-08	2008-09	2009-10	2010-11	2011-12
Jun	16.2	6.6	13.0	7.7	13.0	6.2	6.1	105.5	25.9	21.7	32.0	6.7
Jul	6.0	5.5	14.1	8.0	27.2	3.4	2.3	9.8	41.8	4.3	39.0	8.2
Aug	19.0	16.8	6.4	13.0	12.5	7.3	24.3	7.4	62.9	6.3	63.9	13.6
Sep	21.8	11.3	8.7	16.1	10.7	29.7	8.1	68.4	28.6	5.8	63.4	17.5
Oct	24.1	39.3	14.4	42.2	9.0	31.8	2.8	55.7	5.4	9.4	6.1	2.9
Nov	11.3	22.5	3.0	16.0	6.4	21.0	2.9	0.2	14.5	5.1	69.7	1.9
Dec	2.2	9.1	2.3	21.8	4.4	6.0	4.0	9.6	9.6	9.6	34.3	1.9
Jan	5.9	6.3	1.8	13.0	3.0	2.0	1.2	4.7	4.7	4.7	8.6	0.8
Feb	2.9	3.7	1.0	8.7	1.7	0.5	0.2	3.2	3.2	3.2	6.7	3.2
Mar	2.2	2.5	1.3	5.7	0.6	0.5	0.1	2.5	2.2	2.2	4.1	2.2
Apr	4.9	3.3	1.4	8.0	0.9	0.3	0.1	2.9	2.9	2.9	4.4	2.9
May	2.0	1.8	3.7	6.0	1.5	4.2	3.8	0.6	3.7	5.6	7.4	3.7
Annual	**118.5**	**128.7**	**71.2**	**166.1**	**90.8**	**112.8**	**55.8**	**270.4**	**205.3**	**80.7**	**339.5**	**65.3**

For estimating the yield during missing periods, average monthly flows for the respective month has been considered.

B. Annual Yield at Upper and Lower Dams (Mm^3)

The annual yield at upper and lower dam sites has been estimated using catchment area proportionality method and applying rainfall corrections. The results are furnished below:

Dam	2000-01	2001-02	2002-03	2003-04	2004-05	2005-06	2006-07	2007-08	2008-09	2009-10	2010-11	2011-12
Upper	2.9	3.1	1.7	4.0	2.2	2.7	1.4	6.5	5.0	2.0	8.2	1.6
Lower	47.7	51.8	28.6	66.8	36.5	45.4	22.5	108.8	82.6	32.5	136.6	26.3

C. Dependable Annual Yields (Mm^3)

Ranking studies have been carried out using estimated annual yield at dam sites in order to establish the 50%, 75% and 90% dependable years. The probability (p) of occurrence/exceedance of annual yield is established using Weibull's formula, viz.,

$p = m / (N + 1)$

Where,

m - Ranking number

N - No. of years of data (12)

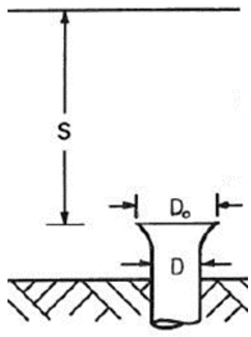
The 50%, 75% and 90% dependable years along with respective annual yield are furnished in the Table given below.

Rank	**Dependa-bility**	**Upper Dam**	**Lower Dam**	**Year**
1	8%	8.2	136.6	
2	15%	6.5	108.8	
3	23%	5.0	82.6	
4	31%	4.0	66.8	
5	38%	3.1	51.8	
6	46%	2.9	47.7	
7	**54%**	**2.7**	**45.4**	2005-06
8	62%	2.2	36.5	
9	69%	2.0	32.5	
10	**77%**	**1.7**	**28.6**	2002-03
11	85%	1.6	26.3	
12	**92%**	**1.4**	**22.5**	2006-07

Annexure - 7.2

Estimation of Submergence Requirement for Upper and Lower Intakes

A. Upper Intake



Definition Sketch

Basic Data

Design discharge (Generation mode),Q = 241 m^3/s

Headrace tunnel diameter, D = 8.0 m

Shape of tunnel = Horse-shoe shaped

Design

Rated Discharge (Qr)	=	241.0	m^3/s			
Overload capacity	=	0.0	m^3/s			
Flushing discharge	=	0.0	m^3/s			
Maximum Discharge (Qmax)	=	245.0	m^3/s			
Diameter of headrace tunnel (D)	=	8.0	m	=	26.25	ft
Min. water level at intake	= RL.	861.0	m			
Cross-section area (A)	=	53.08	m^2			
Velocity of flow (V)	=	4.62	m/s	=	15.14	ft/s

Gordon's Formula for Submergence

Gordon's Formula for submergence	=	C * V * D^0.5			(Ref .ASCE/EPRI GUIDES - 1989, Page 2-12)
Coefficient for straight approach (C)	=	0.3			-1989, Page 2-12)
Submergence required (S)	=	7.09	m	=	23.28 ft
	say	8.00	m		

Submergence as per IS 9761

Froude number, Fr = V / SQRT(g*D)	=	0.52		
Minimum submergence, S = D* (0.5 + 2*Fr)	=	12.34	m	For Fr > 1/3
Minimum submergence required, S =	=	12.34	m	
Actual submergence provided, S =	=	**16.00**	m	
New Zero Elevation	=	**843.0**	RL in m	
Top of bellmouth/intake =		**845.0**	RL in m	
Minimum Drawdown Level, MDDL =	=	**861.0**	RL in m	

Bellmouth

Diameter of bellmouth at end, h = 8.00 m (equal to dia of tunnel)

Salient Results

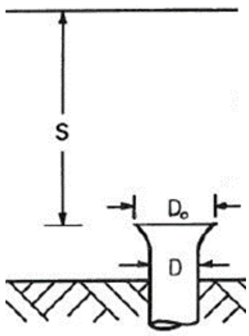
Diameter of the bellmouth at the beginning	=	12.70	m
Length of bellmouth	=	8.00	m
Top of bell mouth of Intake	= RL.	845.0	m

Sizing of Trashrack

Min. water level at intake =	861.00	RL in m
Bottom level of intake =	845.00	RL in m
Circumference of circular intake =	63.8	m
No of openings =	12	
Thickness of pier =	1.30	m
Net length =	46.87	m
Width of opening =	3.91	m
Allowable velocity for hand raking =	0.75	m/s
Height of trashrack =	6.97	m
Provide height of trashrack =	8.00	m
Actual velocity of flow thru' trashrack =	0.65	m/s

So. Provide 12 nos. of gates, each of size 3.9 m Wide & 8 m Height

B. Lower Intake



Definition Sketch

Basic Data

Design discharge (Generation mode),Q = 203 m^3/s

Tailrace tunnel diameter, D = 8.0 m

Shape of tunnel = Horse-shoe shaped

Design

Rated Discharge (Qr)	=	202.6	m^3/s			
Overload capacity	=	0.0	m^3/s			
Flushing discharge	=	0.0	m^3/s			
Maximum Discharge (Qmax)	=	205.0	m^3/s			
Diameter of Tairace tunnel (D)	=	8.0	m	=	26.25	ft
Min. water level at intake	= RL.	281.00	m			
Cross-section area (A)	=	53.08	m^2			
Velocity of flow (V)	=	3.86	m/s	=	12.67	ft/s

Gordon's Formula for Submergence

Gordon's Formula for submergence	=	C * V * D^0.5		(Ref .ASCE/EPRI GUIDES -1989, Page 2-12)
Coefficient for straight approach (C)	=	0.3		-1989, Page 2-12)
Submergence required (S)	=	5.94	m	= 19.48 ft
	say	6.00	m	

Submergence as per IS 9761

Froude number, Fr = V / SQRT(g*D)	=	0.44		
Minimum submergence, S = D* (0.5 + 2*Fr)	=	10.98	m	For Fr > 1/3
Minimum submergence required, S =	=	10.98	m	
Actual submergence provided, S =	=	**14.00**	m	
New Zero Elevation	=	**265.00**	RL in m	
Top of bellmouth/intake =		**267.00**	RL in m	
Minimum Drawdown Level, MDDL =	=	**281.00**	RL in m	

Bellmouth

Diameter of bellmouth at end, h	=	8.00	m (equal to dia of tunnel)
Diameter of the bellmouth at the beginning	=	12.70	m
Length of bellmouth	=	**8.00**	m

Salient Results

Diameter of the bellmouth at the beginning	=	12.70	m
Length of bellmouth	=	8.00	m
Top of bell mouth of Intake	= RL.	267.00	m

Sizing of Trashrack

Min. water level at intake =	281.00	RL in m
Bottom level of intake =	267.00	RL in m
Circumference of circular intake =	63.8	m
No of openings =	12	
Thickness of pier =	1.30	m
Net length =	46.87	m
Width of opening =	3.91	m
Allowable velocity for hand raking =	0.75	m/s
Height of trashrack =	5.83	m
Provide height of trashrack =	7.00	m
Actual velocity of flow thru' trashrack =	0.62	m/s

So. Provide 12 nos. of gates, each of size 3.9 m Wide & 7 m Height

Annexure - 7.3

Estimation of Maximum Water Levels at Upper and Lower Dams

A. Upper Dam

Basic Data

Design flood, Q = 150 m^3/s

Type of spillway = Ogee

Length of spillway, L = 30 m

Deepest river bed level = RL 831.50 m

Crest level of spillway = RL 899.00 m

Maximum water level = RL 900.80 m (assumed)

Estimation of Maximum Water Level

The maximum water level at upper reservoir is calculated as per IS 6934: Hydraulic Design of High Ogee Overflow Spillways - Recommendations. The details of calculations are summarized below.

Design Head, H_d = 1.8 m (RL 900.80 m - RL 899.00 m)

Height of spillway crest measured from river bed, P = 67.5 m (RL 899.00 m - RL 831.50 m)

Un-gated/Overflow Spillway

$$\text{Discharge, } Q = 2/3 \times \sqrt{2g} \times C \times L' \times H^{3/2}$$

Where,

C_d - Coefficient of discharge ($C_d = 2/3 \times \sqrt{2g} \times C$)

L' - Net length of overflow crest (excluding thickness of pier), m

H - Head of overflow, m

C - Non dimensional discharge coefficient (read from Figure - 3 of IS 6934)

C = 0.745 (read from Figure - 3 of IS 6934)

Therefore, $C_d = 2/3 \times \sqrt{19.62} \times 0.745$

= 2.199, say 2.1

(tailwater effect is not considered, as dam height is very high compared to tailwater levels)

$Q = C_d \times L' \times H^{3/2}$

$= 2.1 \times 30 \times 1.8^{3/2}$

= 152 m^3/s, which is higher than 150 m^3/s

Thus, assumed maximum water level of RL 900.80 m will be adequate to pass the design flood of 150 m^3/s estimated for upper dam.

B. Lower Dam

Basic Data

Design flood, Q	= 976 m^3/s
Type of spillway	= Gated ogee (Radial gates)
No. of radial gates, N	= 5 (4 + 1 gate considered in-operative, as per IS 11223)
Size of gates	= 5 m (W) x 7 m (H)
Deepest river bed level	= RL 247.90 m
Crest level of spillway	= RL 299.00 m
Maximum water level	= RL 307.90 m (assumed)

Estimation of Maximum Water Level

The maximum water level at lower reservoir is calculated as per IS 6934: Hydraulic Design of High Ogee Overflow Spillways - Recommendations. The details of calculations are summarized below.

Design Head, H_d = 8.9 m (RL 307.90 m - RL 299.00 m)

Height of spillway crest measured from river bed, P = 51.1 m (RL 299.00 m - RL 247.90 m)

Gated Overflow Spillway (Gates fullu opened condition)

$$\text{Discharge, } Q = 2/3 \times \sqrt{2g} \times C \times L \times H^{3/2}$$

Where,

C_d - Coefficient of discharge ($C_d = 2/3 \times \sqrt{2g} \times C$)

L’ - Net length of overflow crest (excluding thickness of pier), m

N - Number of piers (N = 4)

Kp - Pier contraction coefficient (Kp = 0.01)

Ka - Abutment contraction coefficient (Ka = 0.10)

H - Head of overflow, m

L - Effective length of overflow crest, m

= L’ - 2*H (N*Kp + Ka)

= 20 - 2*8.9 (3*0.01 + 0.10)

= 17.686 m

C - Non dimensional discharge coefficient (read from Figure - 3 of IS 6934)

C = 0.745 (read from Figure - 3 of IS 6934)

Therefore, C_d = 2/3 x √19.62 x 0.745

= 2.199, say 2.1

(tailwater effect is not considered, as dam height is very high compared to tailwater levels)

Q = C_d x L x $H^{3/2}$

= 2.1 x 17.686 x $8.9^{3/2}$

= 986 m^3/s, which is higher than 976 m^3/s

Thus, assumed maximum water level of RL 307.90 m will be adequate to pass the design flood of 976 m^3/s estimated for lower dam.

Annexure - 7.4

Estimation of Evaporation Loss at Upper and Lower Reservoirs

A. Upper Reservoir

Basic Data

Full Reservoir Level, FRL	= RL 899.00 m
Minimum Drawdown Level, MDDL	= RL 861.00 m
Lake evaporation loss	= 1.60 m / year (Visakhapatnam Station)

Estimation of Evaporation Loss

Water spread area at MDDL, A_1	= 0.0810 Mm^2
Water spread area at FRL, A_2	= 0.5803 Mm^2
Mean water spread area, A	= 1/3*[A_1 + A_2 + sqrt(A_1*A_2)]
	= 1/3* [0.0810 + 0.5803 + sqrt(0.0810*0.5803)]
	= 0.2927 Mm^2.
Evaporation loss @ upper reservoir	= 0.2927 x 1.60
	= 0.47 Mm^3/year
	Say 0.5 Mm^3/year
Transmission Loss	= 5% of Evaporation loss @ Upper Reservoir
	= 5/100 * 0.5
	= 0.03 Mm^3/year.

B. Lower Reservoir

Basic Data

Full Reservoir Level, FRL	= RL 306.00 m
Minimum Drawdown Level, MDDL	= RL 281.00 m
Lake evaporation loss	= 1.60 m / year

Estimation of Evaporation Loss

Water spread area at MDDL, A_1	= 0.7611 Mm^2
Water spread area at FRL, A_2	= 1.5923 Mm^2
Mean water spread area, A	= 1/3*[A_1 + A_2 + sqrt(A_1*A_2)]
	= 1/3* [0.7611 + 1.5923 + sqrt(0.7611*1.5923)]

	= 1.1514 Mm^2.
Evaporation loss @ lower reservoir	= 1.1514 x 1.60
	= 1.84 Mm^3/year
	Say 1.9 Mm^3/year
Transmission Loss	= 5% of Evaporation loss @ Lower Reservoir
	= 5/100 * 1.9
	= 0.10 Mm^3/year.

Chapter - VIII
Power Potential and Installed Capacity

8.1 Type of Scheme

The type of power plant envisaged near the project site is a Pumped Storage Hydro Electric Project with an installed generating capacity of 1200 MW. The scheme of operation considered for Kurukutti PSP is weekly regulation to meet the peak demand of about 7 hours of peak power in a week (except Sundays). Off-peak pumping hours are considered as 7 hours on week days with balance pumping on Sundays required for weekly regulation. The net storage required in the reservoirs for the envisaged weekly cycle of operation is estimated to be 11.0 Mm^3.

8.2 Optimization of Storage Capacities of Reservoirs & Related Parameters

8.2.1 *Location of Dams*

a) Upper Dam

The location of upper dam/reservoir suggested by AREMI was found to be situated in the state of Odisha. In order to avoid land acquisition issues and inter-state disputes between Andhra Pradesh and Odisha, upper dam site(s) located in Odisha have not been considered for the project. Several alternate locations were identified duly considering the aspects of storage capacity available, avoidance of forest land, maximization of head, etc. Accordingly, upper dam with a longitude of 83° 02' 40.4'' E and latitude of 18° 36' 52'' N was selected.

b) Lower Dam

Several alternate locations for lower dam were studied duly considering aspects like maximization of head, minimum length of water conductor system, avoidance/minimize submergence of forest land and adequate storage capacity to meet the weekly regulation of both Kurukutti & Karrivalasa PSPs. Accordingly, the location of lower dam was selected with a longitude of 83° 04' 45.6'' E and latitude of 18° 36' 33.8'' N.

The above location of upper and lower dams were selected keeping in view the above mentioned considerations and considered for further studies, pending confirmation based on actual geological and geotechnical investigations, which needs to be carried out during DPR stage.

8.2.2 *Storage Capacity of Reservoirs*

There will be loss of storage in both upper and lower reservoirs due to causes like evaporation, transmission and seepage. A pumped storage project does not require continuous flow of water as in a conventional hydropower plant and stored water in the reservoir is recycled. However, the annual losses in storage in both the reservoirs due to evaporation etc., need to be recharged during monsoon. Therefore, provision for additional storage in the reservoirs will have to be made to facilitate planned operation of the PSS even at the critical periods when the storage in the reservoirs is at a minimum. Additional storage to make up for the losses could be made either in the Upper reservoir, Lower reservoir or both. As explained earlier, the losses in upper and lower reservoirs has been accommodated in the lower reservoir itself.

Possibility of optimizing the storage capacity of reservoirs and dam locations could be reviewed further during DPR stage after carrying out detailed geological, geotechnical investigations and other inter-alia related studies.

a) Upper Reservoir

The Full Reservoir Level (FRL) of upper dam has been kept in such a manner that the required storage capacity to meet the weekly regulation of PSP is achieved with least possible dam height in order to minimize the extent of submergence. Accordingly, FRL of upper dam has been fixed at RL 899.00 m, with a gross storage capacity of 12.6 Mm^3.

b) Lower reservoir

In order to optimize the project cost and land acquisition required for implementation of proposed projects, it has been suggested to accommodate the storage of lower reservoir required for weekly regulation of both Kurukutti and Karrivalasa PSP's at same location. Accordingly, the location of dam and reservoir parameters have been fixed duly considering the above aspects.. Accordingly, FRL of lower dam has been fixed at RL 306.00 m. The gross storage in the lower reservoir at FRL and MDDL are 38.7 Mm^3 and 9.4 Mm^3 respectively.

8.3 Optimization of Installed Capacity

The installed capacity of a typical PSP is dependent on i) demand for peak power ii) availability of pumping energy and iii) Reservoir storages and head available at the site. As explained in Chapter - II, large scale solar parks and non-conventional energy sources like Wind are being implemented in the State of Andhra Pradesh and Southern Region. Owing to highly seasonal/intermittent nature of above sources, development of suitable energy storage system for power and energy shifting is gaining increased focus in the present context. Adequate surplus power required for pumping would be available during day time once proposed solar plants become operational.

Weekly Regulation and Required Storage

The requirement of net storage is same for both upper and lower reservoirs, since water is recycled during weekly regulation. A detailed study has been carried out to establish the requirement of net storage in the reservoirs and the results are presented in Table - 8.1 considering various parameters such as efficiencies in turbine and pumping modes, charge-discharge ratio, system losses etc. The table shows the results for a range of installed capacities from 1000 MW to 1300 MW. The weekly regulation of reservoirs has been worked out considering 7 hours of peak generation and 7 hours of pumping on week days.

Table - 8.1: Net Storage Requirement in Reservoirs for Weekly Regulation

Sl. No.	Generation (MW)	Net Storage (Mm^3)	Generation Hours in a Week	Pumping Hours in a Week
1.	1000	8.7	42	49.2
2.	1050	9.2	42	49.3
3.	1100	9.8	42	49.5
4.	1150	10.3	42	49.8
5.	1200	11.0	42	50.0
6.	1250	11.6	42	50.2
7.	1300	12.2	42	50.5

As seen from above table, required net storage will be 11.0 Mm^3 for an installed capacity of 1200 MW. Further increase in net storage requirement will necessitate increase in dam height and extent of submergence, which is not desirable. It is found that the extent of submergence increases by about 1.5 Hectares and 3.3 Hectares for every 1 m increase in dam height for upper and lower dams respectively. Also, the extent of forest area submerged under the lower reservoir is increasing with increase in capacity beyond 1200

MW. Prima-facie, installed capacity of Kurukutti PSP has been restricted to 1200 MW and the above aspects could be further reviewed during DPR stage to check the possibility of further enhancement of installed capacity.

To pump back the balance water from lower reservoir to the upper at the end of weekly cycle, 8.0 hours of pumping will be necessary on Sundays considering the efficiency and charge-discharge ratio of pump-turbine units.

a) Installed Capacity

For reasons described above, an installed capacity of 1200 MW is suggested to be adopted for the project from the demand and availability of storage in the reservoirs. The number of off-peak pumping needed on Sundays will be 8.0 hours.

b) Number of Units

For the selected installed capacity of 1200 MW and head available at project site, five (5) pump-turbine-generator (PTG) units are recommended. The details of selection of number of units is covered in Chapter on Electro-Mechanical works.

8.4 Operating Criteria of the PSP

a) Storage Requirement

The pump turbine is planned to be operated with weekly regulation considering 7 hours of generation and 7 hours of pumping on week days with balance pumping on Sundays. The weekly operation table of upper and lower reservoirs are shown in Table - 8.2.

Table - 8.2: Weekly Operation Table for Lower and Upper Reservoirs

Day	Lower Reservoir				Upper Reservoir			
	Storage at Beg.	Inflow	Storage at End	Outflow	Storage at Beg	Outflow	Storage at End	Inflow
	Mm^3	Mm^3	Mm^3	Mm^3	Mm^3	Mm^3	Mm^3	Mm^3
Mon	0.0	6.1	6.1	5.1	11.0	6.1	4.9	5.1
Tue	1.0	6.1	7.0	5.1	10.0	6.1	4.0	5.1
Wed	1.9	6.1	8.0	5.1	9.1	6.1	3.0	5.1
Thu	2.9	6.1	9.0	5.1	8.1	6.1	2.0	5.1
Fri	3.9	6.1	9.9	5.1	7.1	6.1	1.1	5.1
Sat	4.8	6.1	10.9	5.1	6.2	6.1	0.1	5.1

Day	Lower Reservoir				Upper Reservoir			
	Storage at Beg.	Inflow	Storage at End	Outflow	Storage at Beg	Outflow	Storage at End	Inflow
	Mm^3	Mm^3	Mm^3	Mm^3	Mm^3	Mm^3	Mm^3	Mm^3
Sun	5.8	-0.7	5.1	5.1	5.2	-0.7	5.9	5.1

As seen from the above table, the maximum net storage required for 1200 MW PSP is about 11.0 Mm^3.

b) Availability of Pumping Energy

The pumping energy required annually is estimated to be 3440 Mu and as explained in Chapter-II, 'Justification of the Project from Power Supply Angle', about 7 hours of off-peak power for pumping is available during day on week days and during extended duration on Sundays.

c) Annual Generation

In a year, the planned peak power generation will be for 2190 hours considering the rate of 6 days per week and 7 hours per day. However, most pumped storage plants have scheduled annual programs for inspections of machinery, instrumentation, controls and structures. The scheduled annual outages span about two week period for each unit. Thus, about 12 days of generation could be lost due to annual maintenance. Therefore, on an average there will be about 301 days of generation annually or 2106 hours in a year. Thus, the average annual energy generation from the PSP is expected to be 2527 Mu.

d) Annual Requirement of Pumping Energy

The pumping will have to be carried out for 50.0 hours (i.e., 42 hours on week days and 8.0 hours on Sundays) per week, considering the pumping capacity of 1320 MW. As explained earlier, about 12 days of outages per year will be required for annual maintenance and overhaul. Therefore, the number of net pumping hours will be 2506 in a year and the energy required for pumping works out to 3308 Mu per annum. The ratio of generation to pumping energy works out to about 76%.

8.5 Cycle Efficiency of the Scheme

The following parameters of the pump-turbine have been considered for power studies based on discussions with vendors and experience in similar PSP's in India:

- Efficiency of Pump = 94%
- Efficiency of Motor and Transformer = 98%
- Efficiency of water passages in Pumping mode = 98.5%
- Efficiency of Turbine = 92%
- Efficiency of Generator and Transformer = 98%
- Efficiency of water passages in Generation mode = 99%
- Allowance for operation under other than optimum efficiency = 98.0%
- Charge/Discharge Ratio = 1.1
- Head loss (Generation mode) = 20 m
- Head loss (Pumping mode) = 14 m

The details of head loss calculations considering generation mode is furnished in Annexure - 8.1.

Annexure - 8.1

Estimation of Head Loss in Generation Mode

Data									Trashrack	R	0.44	Cl.7.1 IS:11388			
ν	1.006E-06	m^2/s								K	1.06				
											1.06	say			
Sl. No.	**Q (m^3/s)**	**W (m)**	**H (m)**	**D (m)**	**L (m)**	**Pipe Material**	**ε (mm)**	**v (m/s)**	**v^2 / 2g (m)**	**Re**	**Darcy's f**	**ζfr (= f L / D)**	**h_f (m)**	**Reference**	**Remarks**
1	241.00	46.80	8.00					1.29	0.084			1.064	0.09	IS 4880 (Part 3) 50% Clogging	Circular Trashrack
2	241.00	40.80	8.00					0.74	0.028			0.100	0.01	cl: 4.6, IS 4880 (Part 3)	Gate Slots (Intake Gate & Stoplog)
3	241.00	126.68						1.90	0.184			0.050	0.01	Table-1 Sl. No.vii IS 4880 (Part 3)	Circular Bell-mouth Entrance
4	241.00	126.68	53.08				1.90	4.54	0.866			0.100	0.09	cl: 4.4.1, IS 4880 (Part 3)	Gradual contraction at Entrance
5	241.00			8.00	1010	Concrete Lined	1.00	4.54	1.051	3.61E+07	0.013	1.586	1.67	ASCE/EPRI Vol.2-Waterways	HRT (Horse Shoe- Shaped) - friction loss
6	241.00			8.00				4.54	1.051			0.150	0.16	IS 4880 (Part 3), Fig.1 IS 2951 (Part-II)	HRT - Vertical Bend Loss (R/D = 16/8 = 2)
7	241.00			8.00				4.54	1.051			1.000	1.05	IS 4880 (Part 3)	HRT (Exit)
8	241.00	6.80	6.80					5.21	1.385			0.100	0.14	IS 4880 (Part 3)	Surge shaft - Gate loss
9	241.00			6.80				6.64	2.244			0.250	0.56	Table-1 Sl. No.v, IS 4880 (Part 3)	Pressure shaft (Entry) Slightly rounded entrances considered
10	241.00			6.80	1800	Steel	0.03	6.64	2.244	4.49E+07	0.008	2.027	4.55	ASCE/EPRI Vol.2-Waterways	Pressure shaft friction loss
11	241.00			6.80		Steel		6.64	2.244			0.150	1.35	IS 4880 (Part 3), Fig.1 IS 2951 (Part-II)	Pressure shaft - Bend Losses (4 nos.), r/D = 2
12	241.00			6.80		Steel		6.64	2.244			0.350	0.79	IS 2951 (Part-II), Table 2	PS Trifurcation
13	96.40			4.50			2.65	6.06	1.513			0.100	0.15	cl: 4.4.1, IS 4880 (Part 3)	Gradual contraction at PS Trifurcation
14	96.40			4.50	70	Steel	0.03	6.06	1.873	2.71E+07	0.008	0.127	0.24	ASCE/EPRI Vol.2-Waterways	Branch PS - Trifurcation to PS Bifurcation Friction Loss
15	96.40			4.50				6.06	1.873			0.320	0.60	IS 2951 (Part-II), Table 2	PS Bifurcation
16	48.20			4.50	140	Steel	0.03	3.03	0.468	1.36E+07	0.009	0.267	0.12	ASCE/EPRI Vol.2-Waterways	Bifurcation to Unit-1 Friction Loss
17	48.20			4.50				3.03	0.468			0.090	0.04	Fig.3, IS 11625	Branch PS Bend Loss (1 no)
18	48.20			4.50			3.03	15.34	11.53			0.100	1.15	cl: 4.4.1, IS 4880 (Part 3)	Gradual contraction at BFV
19	48.20			2.00				15.34	12.00			0.300	3.60	IS 11625	BFV (1 no)
20	48.20	5.00	4.00					2.41	0.296			0.100	0.03	cl: 4.6, IS 4880 (Part 3)	Draft Tube Gate (Groove Loss) 1 no.
21	48.20			4.0			2.41	3.63	0.38			0.850	0.32	IS 2951 (Part-II)	Expansion Loss
22	48.20			4.0	100	Concrete	1.00	3.63	0.673	1.44E+07	0.014	0.362	0.24	IS 4880 (Part 3)	TRT Branch Friction Loss
23	48.20			4.00				3.63	0.673			0.100	0.07	IS 4880 (Part 3), Fig.1 IS 2951 (Part-II)	TRT - Bend Loss - 1 no., r/D = 4
24	48.20			4.00				3.63	0.673			0.425	0.29	IS 2951 (Part-II), Table 3	TRT junction loss
25	241.00			8.00	530	Concrete	1.00	4.54	1.051	3.61E+07	0.013	0.832	0.87	ASCE/EPRI Vol.2-Waterways	Tailrace Tunnel Friction Loss
26	241.00			8.00				4.54	1.051			0.150	0.16	IS 4880 (Part 3), Fig.1 IS 2951 (Part-II)	TRT - Vertical Bend Loss (R/D = 16/8 = 2)
27	241.00			8.00				4.54	1.051			1.000	1.05	IS 4880 (Part 3)	Tailrace Tunnel Exit Loss
28	241.00	126.68	53.08				1.90	4.54	0.87			0.250	0.22	IS 2951 (Part-II)	Gradual Expansion at Outlet
29	241.00	126.68						1.90	0.184			0.050	0.01	Table-1 Sl. No.vii IS 4880 (Part 3)	Circular Bell-mouth at Outlet
30	241.00	40.80	7.00					0.84	0.036			0.100	0.01	cl: 4.6, IS 4880 (Part 3)	Gate Loss at Outelt
31	241.00	46.80	7.00					1.47	0.110			1.064	0.12	IS 4880 (Part 3) 50% Clogging	Trashracks at Outlet
												Total	19.74	m	
												Say	**20.00**	m	

Chapter - IX
Design of Civil Structures

9.1 Structures and Layout

Kurukutti project is a Pumped Storage Project envisaging generation of 1200 MW of peak power during week days. It envisages two reservoirs i.e., Upper and Lower at project site utilizing an available gross head of about 589 m. The water from upper reservoir will be utilized for generating power during peaking hours on week days (from Monday to Saturday) and during off-peak periods, water from lower reservoir shall be pumped back to upper reservoir (from Monday to Saturday and on Sundays) using surplus off-peak power available from solar and wind projects. A schematic layout of project is shown in Figure - 9.1 and detailed layout of project is given in Exhibit - 11.

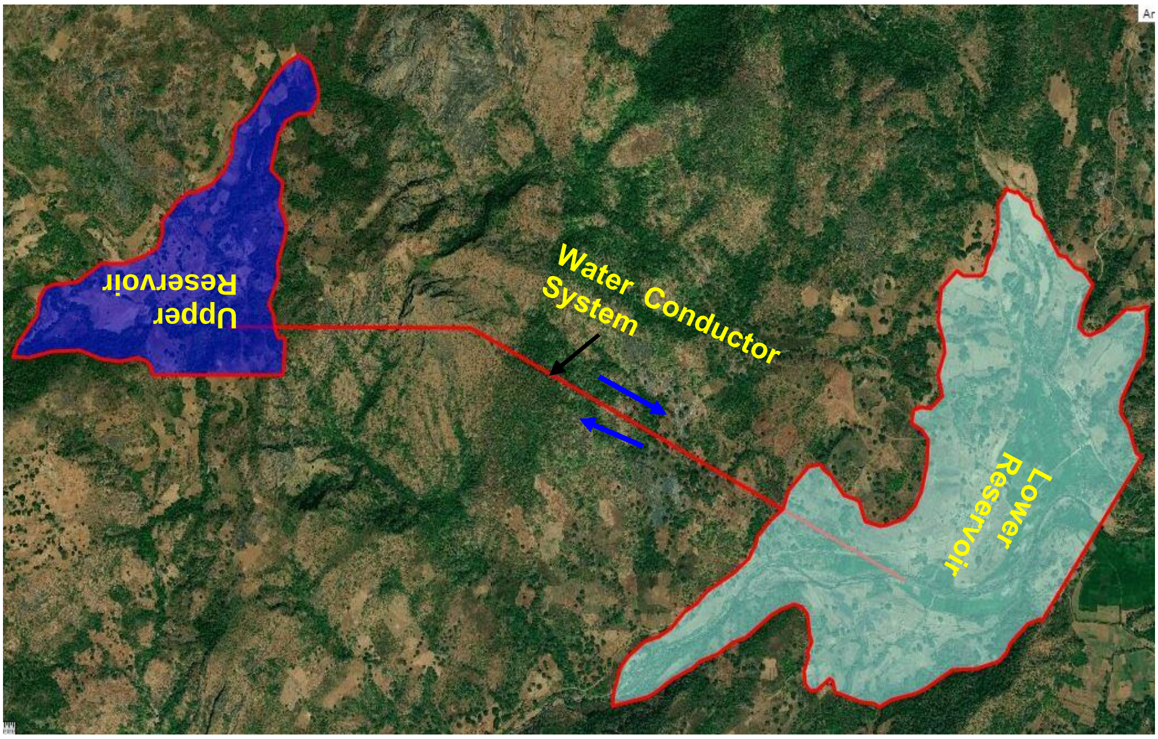


Figure - 9.1: Schematic Layout of Kurukutti PSP

During turbine mode, a vertical intake draws water from upper reservoir into a headrace tunnel of 8 m finished diameter. Subsequently, a steel lined pressure shaft of 6.8 m diameter takes-off from the downstream end of surge shaft, which further divides into five (5) branches of 4.5 m diameter each near the powerhouse. Water flows from these branches to the pump-turbine units (Francis type) located inside the shaft type powerhouse.

The water from turbines is led to the tailrace tunnel of 8.0 m diameter through draft tubes and finally into the lower reservoir through an outlet structure.

During pumping mode, water is drawn from lower reservoir through a vertical intake at tailrace tunnel and led back into the upper reservoir through the same water conductor system as briefed above.

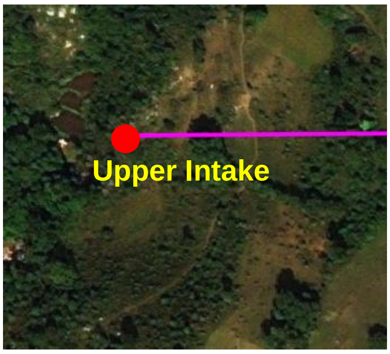
The proposed Kurukutti PSP (5 x 240 MW) envisages following major civil structures:

1) **Upper Dam** (RCC-Roller Compacted Concrete): Crest length 680 m, maximum height 71 m above the deepest river bed level. The gross storage capacity of Upper reservoir is 12.6 Mm^3.
2) **Lower Dam** (RCC-Roller Compacted Concrete): Crest length 740 m, maximum height 62 m above the deepest river bed level. The gross storage capacity of Lower reservoir is 38.7 Mm^3.
3) **Upper Intake/Outlet:** Vertical type, circular intake, 20.3 m dia., 12 nos. trashrack bays, each with a size of 3.9 m (W) x 8.0 m (H).
4) **Lower Intake/Outlet:** Vertical type, circular intake, 20.3 m dia., 12 nos. trashrack bays, each with a size of 3.9 m (W) x 7.0 m (H).
5) **Headrace Tunnel:** 1010 m (length), 8.0 m (diameter), horse-shoe shaped, concrete lined.
6) **Surge Shaft:** Restricted orifice type, 10 m diameter, 105 m high, circular, concrete lined.
7) **Pressure Shaft**: 1800 m (length), 6.8 m (diameter), steel lined and branching near powerhouse, each with 4.5 m diameter and 140 m long.
8) **Shaft Type Powerhouse**: Five (5) nos. of shafts, each of 29 m finished diameter, circular shaped and concrete lined
9) **Tailrace Tunnel:** 530 m (length), 8.0 m (diameter), horse-shoe shaped, concrete lined.
10) **Pothead Yard:** 280 m x 70 m
11) **Approach road**
    - Approach road :
      Strengthening of existing village roads - 5 km
      Construction of new road - 10 km

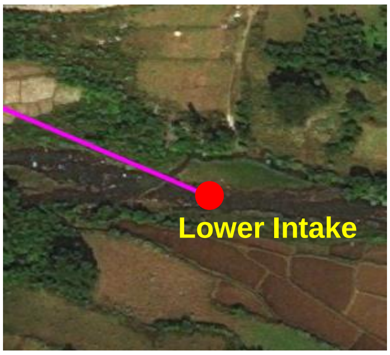
9.2 General

9.2.1 *Headworks - Site & Vicinity*

The location and extent of upper and lower reservoirs proposed for Kurukutti PSP is shown in Figure - 9.1. Upper intake is proposed to be located within the reservoir submergence upstream of dam site. The site essentially comprises a few habitations, trees and shrubs within the water spread area and is well connected by means of existing village roads (un-metalled).



Lower intake is proposed to be located within the submergence area of lower reservoir. Lower dam site is located near Kurukutti village and is accessible by means of existing district road.



9.2.2 *Reasons for Choice of the Layout*

A pumped storage project essentially comprises two (2) reservoirs for carrying out generation and pumping operations required for energy/power storage. The location of upper dam is selected based on storage requirements and geological considerations. On the other hand, location of lower dam is selected keeping in view the head availability, length of water conductor system and storage capacity to meet net storage required for weekly regulation of both Kurukutti & Karrivalasa PSP's. The water conductor system is aligned along the left flank of upper reservoir considering the location of lower reservoir and site conditions. Further, there are only a few nallah crossings along the proposed alignment and also has adequate rock cover for the underground works like headrace tunnel and pressure shaft.

9.2.3 Dams

The project involves construction of two (2) dams, viz., 71 m high (above deepest RBL) and 680 m long upper dam and 62 m high(above deepest RBL) and 740 m long lower dam. The type of dam could be of rockfill type or concrete type considering that good rock foundation is expected to be available in the river bed. Major considerations in the selection of type of dam are: availability of suitable construction material in the vicinity of required quantity, safety, capital cost, ease of construction, operational flexibility. Overflow portion of the dam is proposed to be constructed in mass concrete with high grade concrete topping for spillway and energy dissipation arrangement. Two (2) alternative types of non-overflow portion of dam have been considered in the study as given below:

a) Roller Compacted Concrete (RCC) dam
b) Rockfill Dam

RCC dam is considered as against conventional concrete dam owing to its cost-effectiveness, better quality control and faster completion time. A RCC dam utilizes fly ash and is economical compared to a conventional concrete dam. Since adequate quantity of fly ash is expected to be available from thermal power plants at Vizag Steel Plant, 2000 MW NTPC Simhadri thermal power plant and 1040 MW Hinduja National Thermal Power Station, close to the project site (100 - 200 km) and construction of RCC dam being faster compared to conventional concrete, RCC dam is preferred over conventional concrete dam.

Similarly, rockfill dam has been considered as against other embankment dams (earthen dams) considering its inherent advantages like minimal settlement problems, increased overall stability of dam and high resistance to earthquake loading. Out of the various types of rockfill dams available, Asphalt Faced Rockfill Dam (AFRD) has been considered owing to several advantages (like seepage control, capital cost, etc) compared to other rockfill type of dams.

Accordingly, a preliminary techno-economic comparison is made between RCC and AFRD dam types to select the most suitable dam type for proposed upper and lower dams. The resulting summary of studies is given in Table - 9.1.

Table - 9.1: Comparison of Dams

Sl. No.	Parameter	RCC	AFRD
1.	Quantity of Concrete	12.5 Lakh m^3	1.5 Lakh m^3
2.	Quantity of Rockfill	-	51 Lakh m^3
3.	Construction time	Less	More

Sl. No.	Parameter	RCC	AFRD
4.	Quality	High	High
5.	Ease of construction	Relatively easy	Relatively difficult
6.	Capital cost	BASE	(-) 13%

As seen from the above table, the overall capital cost of AFRD dam is less by about 13% as compared to RCC dams. On the other hand, the overall quantity of rockfill / aggregate required for AFRD is found to be significantly higher than RCC dam. For the present study, the option of RCC dam is adopted for both upper and lower dams, considering the following aspects:

a) The height of RCC dam will be lower as compared to AFRD due to lesser wave run up.
b) Volume of rock to be quarried for RCC dam is about one fourth the requirement of AFRD.
c) Production and handling of huge quantities of different materials in various zones is comparatively more difficult in AFRD vis-à-vis RCC dam.
d) Construction time required for completion of AFRD is more compared to RCC dam and is relatively difficult to construct.
e) Risk of failure is relatively more for a AFRD dam compared to a RCC dam.
   This is not desirable as the river reach and the area downstream of proposed project site is relatively flatter with significant habitations and agricultural lands.

However, the option of AFRD will be further reviewed during DPR stage.

9.2.4 *Penstock vs Pressure Shaft*

Due to the requirement of deep setting for the pump-turbine-generator units below the minimum drawdown level of lower reservoir, an underground pressure shaft is inevitable/unavoidable for a pumped storage project, near the powerhouse. However, considering the project terrain along the water conductor system, both options of penstock (surface/above ground) and pressure shaft (underground) are technically feasible for the reach of water conductor system between surge shaft and start of branch pressure shafts. Based on preliminary cost comparison of both options, it is found that overall cost of penstock per metre length is less by about 15%-20% as against pressure shaft.

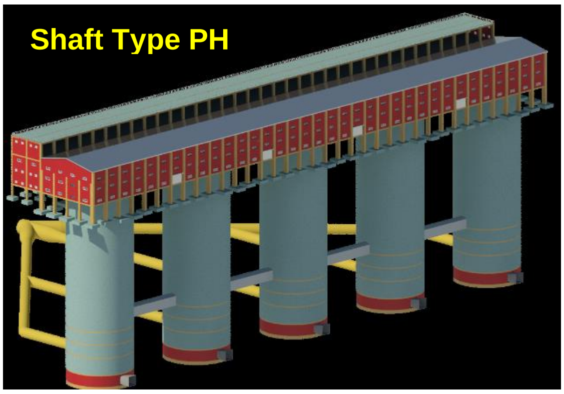
However, penstock option is not considered for the following reasons:

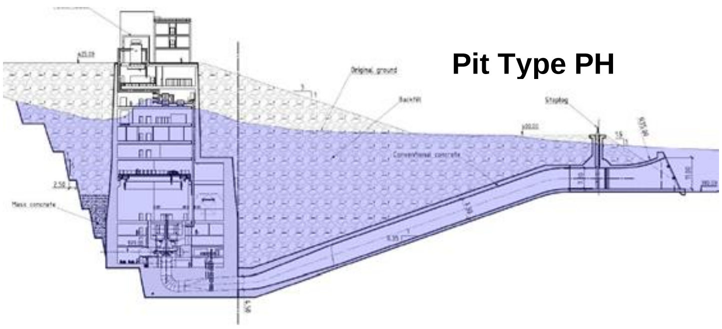
a) Construction difficulties (as ground profile is steep & diameter of penstock is high)
   Transportation & laying of large diameter penstock on the hill top along a steep ground profile is difficult and also requires additional ground anchorages, anchor blocks and ring girder supports.
b) Environmental issues
   Increase in land requirement/acquisition considering right-of-way for the surface penstock
c) Risk of failure due to poor maintenance
   Considering a long project life of 40 years, proper maintenance is required along the surface penstock to avoid damage to penstock due to tree growth and/or animal movements. In the event of damage/failure of penstock, it will lead to substantial loss to human lives and environment in the downstream reaches of the project, as the penstock carries water at high pressures (~ 600 m)
d) Higher head loss due to requirement of more number of bends

Considering the above aspects, a steel lined pressure shaft option is adopted for the project

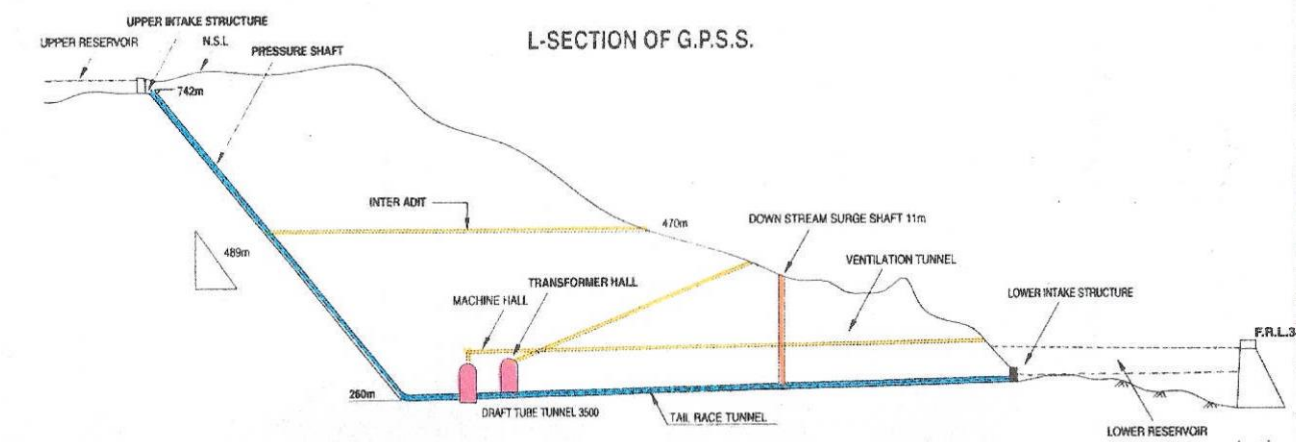
9.2.5 *Powerhouse*

Two alternative types of powerhouse viz., Surface/semi-underground (Shaft type and pit type) and underground powerhouse (Cavern type) have been reviewed for project. Schematic sectional view of different types of powerhouses is shown below:





Surface / Semi-Underground Powerhouses (Typical)
(Shaft type PH & Pit Type PH)



Underground / Cavern Type Powerhouse (Typical)

Underground / cavern type powerhouse typically requires construction of multiple adits and access tunnels to provide access for various utilities and equipment, capital cost and construction time required for project will be higher than a surface powerhouse. Further, operation and maintenance costs for an underground powerhouse is relatively higher due to requirement of additional expenditure towards lighting, ventilation and air conditioning. Further, geological considerations play a major role in selection of ideal site with adequate rock cover for location of underground powerhouse.

A preliminary comparison between different types of powerhouses has been made for the project and details are furnished in Table - 9.2.

Table - 9.2: Techno-Economic Comparison of Powerhouses

Sl. No.	Description	Surface / Semi-Underground Powerhouse		Underground / Cavern PH
		Shaft Type	Pit Type	
1.	Powerhouse size	5 shafts each of 29 m dia.	200 m (L) x 30 m (W) x 108 m (H)	200 m (L) x 24 m (W) x 54 m (H)
2.	Transformer Outdoor yard	280 m (L) x 70 m (W)	180 m (L) x 70 m (W)	160m (L) x 21.5 m (W) x 21 m (H)
3.	Access Tunnels to PH	-	-	8m dia & 2km long
4.	Cable & ventilation tunnel	-	-	6m dia & 500m long
5.	Capital cost	Base	Base	(+) 12%
6.	Construction time	Base	Base	(+) 1 year

Considering the stable geological conditions prevailing at project site (no risks due to landslides, avalanches, rock falls, etc), cost & construction advantages, shaft type PH with outdoor switchyard has been adopted. However, the option of Silo / Pit / underground type powerhouse will also be explored during DPR stage, after carrying out detailed geo-technical investigations (as an open pit with 108 m deep open pit may necessitate additional support systems for stability depending on the rock type, which needs to be explored and evaluated based on detailed investigations and studies).

9.3 Geology and Seismicity

A preliminary assessment of the site geology, geo-technical and seismicity aspects of the project has been made based on regional geological maps published by Geological Survey of India, published literature and limited information gathered during site reconnaissance. Detailed investigations will be carried out during DPR stage to assess the geological, geo-technical and seismicity aspects of suggested location and layout of project before finalization of project layout and cost. Preliminary geological assessment of project area is covered in Chapter - V (Survey and Investigation).

9.4 Alternative Layout Studies

9.4.1 Earlier Proposal - AREMI

Australian Renewable Energy Mapping Infrastructure (AREMI), Government of Australia had undertaken mapping of potential pumped storage sites globally and made a preliminary assessment of energy storage potential along with dam height and layout for each PSP site. The salient details and parameters are furnished in Table - 9.3 and the proposed layout/scheme suggested by AREMI is shown in Figure - 9.2.

Table - 9.3: Details of Kurukutti PSP (AREMI)

Upper Reservoir		Lower Reservoir		Scheme	
Reservoir Ref.	n18_e083_RES54955	Reservoir Ref.	n18_e083_RES50279	Class	B
Elevation	951	Elevation	160	Head (m)	790
Latitude	18.5608	Latitude	18.6161	Separation (km)	12
Longitude	83.0011	Longitude	83.2056	Average Slope (%)	7
Area (ha)	343	Area (ha)	1133	Volume (GL)	91.1
Volume (GL)	98.8	Volume (GL)	98.5	Water to Rock (Pair)	4.3
Dam Wall Height (m)	70.4	Dam Wall Height (m)	17.9	Energy (GWh)	150
Dam Length (m)	2868	Dam Length (m)	5736	Storage time (h)	18
Dam Volume (GL)	9.2	Dam Volume (GL)	2.6		
Water/Rock Ratio	10.7	Water/Rock Ratio	38.3		

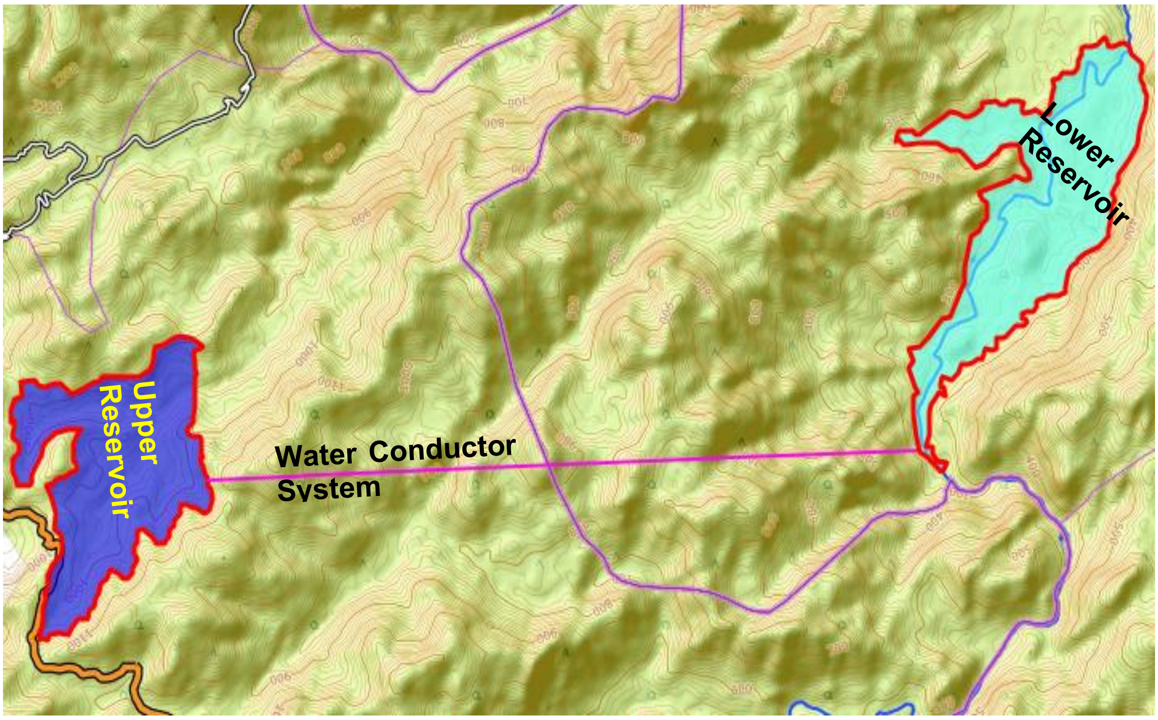


Figure - 9.2: Schematic Layout of Kurukutti PSP, AREMI

The location of project components and the layout of PSP suggested by AREMI was reviewed based on available data and preliminary desk studies. Further, upper and lower dam sites were visited during the site visit and the following observations are made:

a) Upper dam is proposed across a minor nallah draining into Boduru Gedda river (a tributary of Suvarnamukhi river), near Borhapadu village in Odisha. The upper reservoir will involve large scale submergence of agricultural lands and habitations at Porhapadar, Siura and Dhandugurha villages. The total area that will be submerged is about 343 Hectares and entirely falls under the boundary of Odisha State.
b) Lower dam is proposed across Pedda Gedda river near Kurukutti village in Andhra Pradesh. The total area that will be submerged is about 424 Hectares.
c) Upper dam/reservoir, intake and about 50% of the underground water conductor system falls within the administrative boundary of Odisha.

The scheme suggested earlier by AREMI was not considered for further studies, as it involves large scale submergence of agricultural lands and habitations in the state of Odisha and Andhra Pradesh. Various technically feasible alternative layouts that could be considered for development of proposed PSP has been studied and the details are given in the subsequent sections.

9.4.2 *Considerations for Formulation of Layout(s)*

The following aspects have been considered for formulation of alternative layouts:

a) Utilization of available head at project site to the maximum extent feasible.
b) Development of economical and optimized layout.
c) Ease of construction.
d) Minimal area of land acquisition to accommodate various project components.
e) Avoid / minimize submergence of forest land.
f) Avoidance of land acquisition in the state of Odisha

9.4.3 *Formulation of Alternative Layout(s)*

The identification/formulation of alternative layouts has been made based on topographical aspects using latest 30 m resolution Digital Elevation Model (DEM) obtained from SRTM and information obtained from Survey of India toposheet. The methodology adopted for formulation of alternative location of dams/reservoirs and other project components is briefly summarized herewith:

a) Lower dam location suggested by AREMI was reviewed and found that it will involve large scale submergence of habitations at Kurukutti village, which is a major village. Hence, an alternate dam site located about 4.5 km upstream was considered for further study.
b) The above alternate dam site was considered as reference point and area of search was extended upto a radius of 10 km in all the directions. The search area was further divided radially into 5 equal sub-sections, each with a radius of about 2 km.
c) The area was further divided into four (4) quadrants, i.e., NE, SE, SW and NW and the major stream systems in each quadrant where dams could be located were identified. A total of 5 alternate sites for upper reservoir and 2 alternate sites for lower reservoir were identified for Kurukutti PSP (Refer Figure - 9.3).
d) The alternative location of upper and lower dam sites has been fixed duly considering the aspects of maximization of available head, availability of adequate storage capacity and minimizing submergence of agricultural and forest land.

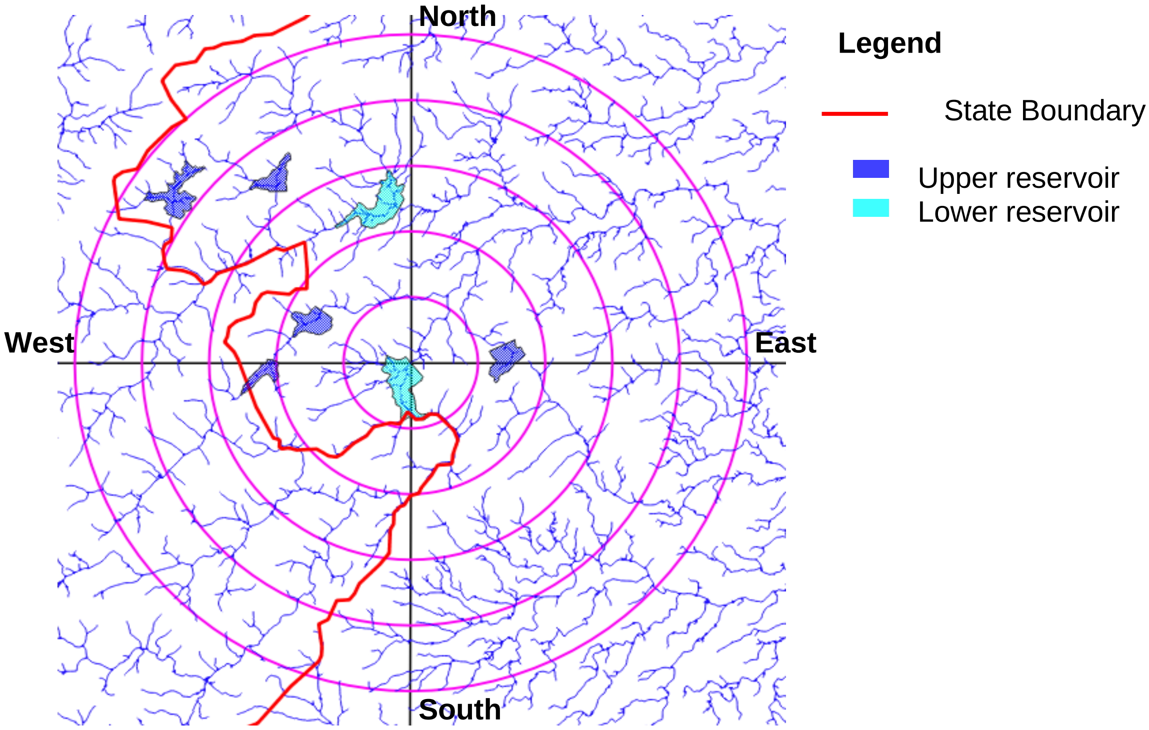


Figure – 9.3: Search Criteria for Formulation of Layouts

e) The above alternative dam locations (5 upper dam sites and 2 lower dam sites) were further considered for formulation of alternative layouts. The location and layout suggested for each of the above five (5) alternatives is given in Exhibit - 10 and tentative project parameters for each of the above alternative layouts along with details like head available, dam height required, length of water conductor system, etc are summarized in the table given below.

Table - 9.4: Project Parameters and Details of Alternative Layouts

Sl. No.	Parameter	Alt-1	Alt-2	Alt-3	Alt-4	Alt-5
I	**Upper Dam/Reservoir**					
1	River Bed Level (RL in m)	830.00	751.00	1075.00	624.00	553.00
2	FRL (RL in m)	900.00	817.00	1127.00	671.00	604.00
3	MDDL (RL in m)	860.00	774.00	1104.00	646.00	575.00
4	Dam Length (m)	680	390	450	680	1650
5	Dam Height (m)	73	69	55	50	54
6	Gross Storage (Mm^3)	12.8	9.4	14.3	15.5	13.4
II	**Lower Dam/Reservoir**					
7	River Bed Level (RL in m)	248.00	247.00	248.00	247.00	247.00
8	FRL (RL in m)	299.00	301.00	299.00	305.00	305.00
9	MDDL (RL in m)	282.00	284.00	282.00	287.00	287.00
10	Dam Length (m)	710	800	710	820	820
11	Dam Height (m)	54	57	54	61	61

Sl. No.	Parameter	Alt-1	Alt-2	Alt-3	Alt-4	Alt-5
12	Gross Storage (Mm^3)	25.4	25.3	25.4	30.9	30.9
III	**Project Parameters**					
13	Gross Head (m)	592	516	822	366	299
14	Length of Water Conductor System (km)	3.7	4.1	6.8	3.1	3.3
15	L/H Ratio	6.3	7.9	8.3	8.5	11.0
IV	**Capacity**					
16	Generation Capacity (MW)	1200	750	1650	730	600

f) Alternative - 5 is not considered for further study owing to higher L/H ratio (L/H ratio > 10) and longer dam lengths compared to other alternatives, which will result in higher capital cost and construction time. Further, head availability and capacity is also less for the above alternative.

g) Alternatives - 2 and 4 are not considered as the installed capacity of these alternatives is significantly lower and also has a higher L/H ratio as compared to Alternative - 1.

h) Alternative - 3 is not considered as L/H ratio is high compared to Alternative - 1 and technically not feasible to be implemented as a single scheme since pump-turbine units are currently not available for such high heads (> 800 m).

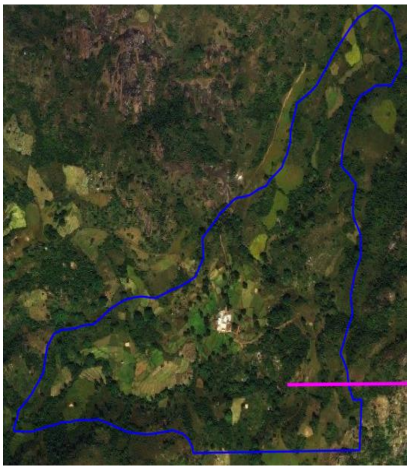
9.5 Choice of Final Layout

As seen from the above table, Alternative - 1 with an installed capacity of 1200 MW utilizing an available gross head of about 592 m is considered for the project owing to its lowest L/H ratio, which indicates that the capital cost will be minimum for the above alternative. Further, it is found that the location of lower reservoir suggested for above alternative could also be used for Karrivalasa PSP, thereby resulting in additional savings in capital cost as well as land requirement for both PSP's. Considering the above aspects, Alternative - 1 is adopted for Kurukutti PSP.

Site visit was undertaken by a team of experts comprising specialists in the field of survey, hydropower, geology and civil designs during the month of January 2021 to ascertain the suitability of selected dam and powerhouse sites for project development. During site visit, it was observed that good founding strata was available at the selected dam and powerhouse sites and geologically the project area was also favourable along the entire length of proposed water conductor system. Accordingly, detailed topographical survey covering the entire project area pertaining to the selected alterative (Alternative - 1) has been carried out to firm-up/finalize the parameters for the proposed project. Based on the analysis of topographical data, alignment of water conductor system has been modified slightly to optimize the overall length of water conductor system and increase the distance between lower intakes and powerhouses so as to avoid any mutual interference during tandem operation of proposed Kurukutti and Karrivalasa PSPs. Further, detailed evaluation of project will be carried out during DPR stage after carrying out geological and geo-technical investigations. The details of finalized layout and project components considered for Kurukutti PSP is given herewith:

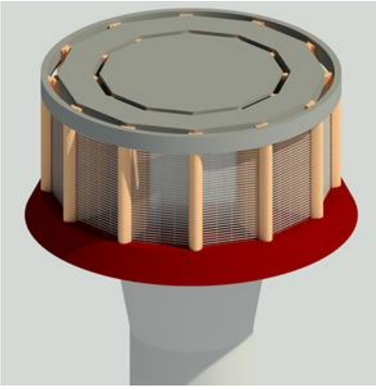
9.5.1 Upper Dam/Reservoir

Upper dam will be located near Chemidipatipolam village. The salient parameters of upper dam are as given below:



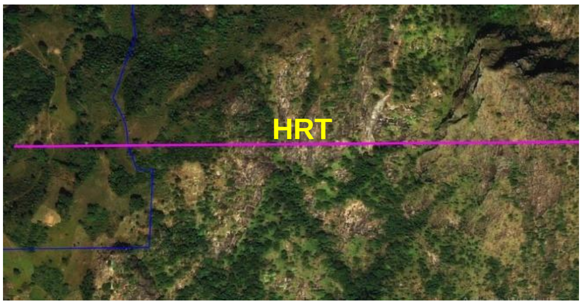
a) FRL - RL 899.00 m
b) MDDL - RL 861.00 m
c) MWL - RL 900.80 m
d) Dam height - 71 m (above deepest RBL)
e) Dam length - 680 m
f) Reservoir submergence - 58 Ha
g) Gross storage - 12.6 Mm^3
h) Spillway - 30 m long (ungated ogee)

9.5.2 Upper Intake



Flows from upper reservoir are diverted to a headrace tunnel through an upper intake (vertical) structure. Based on submergence requirement and considering a margin of 2 m, the top of bell-mouth of vertical intake is planned at RL 845.00 m. Circular intake structure will be provided with twelve (12) nos. of trashrack bays, each of size 3.9 m (W) x 8.0 m (H), so as to prevent entry of trash along with intake gates for isolation of headrace tunnel. The hydraulic design of upper intake is given in Annexure - 7.2 and details of upper intake are shown in in Exhibit-12.

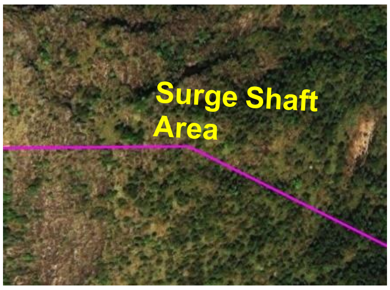
9.5.3 Headrace Tunnel (HRT)



The headrace tunnel will be of horse shoe shaped and 1010 m long. It is proposed to provide concrete lining for the entire length of tunnel. Economic studies have been carried out considering various diameters varying from 6.0 m to 10.5 m to determine the most optimum diameter for the headrace tunnel. Based on preliminary optimization studies carried out, a finished diameter of 9.5 m is found to be optimum for the HRT. However, it is a general practice to choose a slightly sub-optimal smaller diameter for the tunnel to reduce capital cost and avoid construction difficulties due to large diameter tunnels. Based on review of the total evaluated cost, it is found that the incremental benefit that can be realized beyond a tunnel diameter of 8 m is marginal and hence, a finished tunnel diameter of 8.0 m is adopted for the HRT, with a design flow velocity of about 4.54 m/s. The details of optimization studies carried out for HRT are furnished in Annexure - 9.1.

Longitudinal section along the HRT indicating the ground profile and suggested tunnel grade is shown in Exhibit - 12 and typical cross section details are shown in Exhibit - 13. The tunnel alignment has been fixed considering a minimum cover of about 25 m (3 x Tunnel diameter). Based on the preliminary geological inferences, it is most likely that the majority of the tunnel alignment will pass through good to fair rock mass, the tunnel will be free from weak zones like shear zones, faults etc. Considering the type of rock mass, preliminary supports in the form of shotcrete and rock bolts are envisaged during construction. However, the entire tunnel design including supports will be further reviewed during DPR stage based on detailed investigations and lab test results.

9.5.4 Surge Shaft

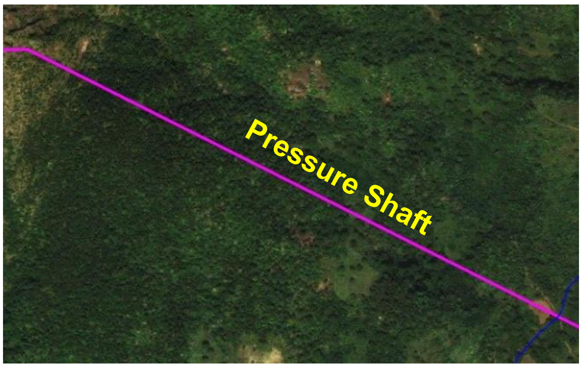


The surge shaft is of restricted orifice type and circular in shape with 10.0 m finished diameter & 105 m high and will be concrete lined for its entire height. Hydraulic design of surge shaft has been carried out as per IS 7396 (Part 1): Criteria for Hydraulic Design of Surge Tanks - Simple Restricted Orifice and Differential Surge Tanks and details are furnished in Annexure - 9.2. Based on preliminary analysis, an orifice diameter of 4.7

m has been adopted for the project and water levels in the surge shaft during maximum upsurge and down surge conditions have been estimated.

Based on the preliminary geological inferences, it is most likely that the majority of the shaft will pass through good to fair rock mass and will be free from weak zones like shear zones, faults etc. Considering the type of rock mass, preliminary supports in the form of shotcrete and rock bolts are envisaged during construction. However, the entire shaft design including supports will be reviewed based on detailed investigations & water hammer studies to be carried out during DPR stage.

9.5.5 Pressure Shaft

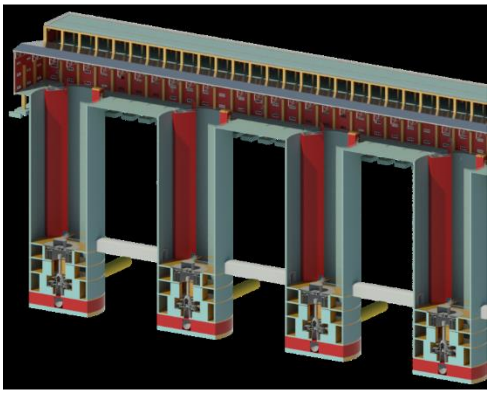


The pressure shaft will be of circular shape and a total length of about 1800 m (which comprises 590 m long vertical shaft and 1210 m long horizontal shaft). Considering the high head of the scheme, long-term stability and O & M aspects, pressure shaft will be provided with steel liner to withstand the internal water pressure and suitably backfilled with concrete. Economic studies have been carried out considering various diameters varying from 6.00 m to 9.60 m to determine the most optimum diameter for the pressure shaft. Based on preliminary analysis, a finished diameter of 6.8 m is adopted, with a design flow velocity of about 6.64 m/s. The details of optimization studies carried out for pressure shaft is furnished in Annexure - 9.1. Longitudinal section along the pressure shaft indicating the ground profile and suggested pressure shaft grade is shown in Exhibit - 12 and cross section details are shown in Exhibit - 13.

Based on the preliminary geological inferences, it is most likely that majority of pressure shaft will pass through good to fair rock mass and will be free from weak zones like shear zones, faults etc. Considering the type of rock mass, preliminary supports in the form of shotcrete and rock bolts are envisaged during construction. However, the entire pressure shaft design including supports will be further reviewed during DPR stage based on detailed investigations and lab test results.

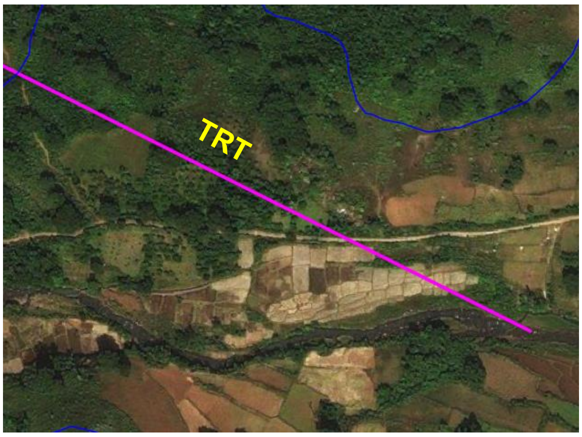
9.5.6 <u>Powerhouse</u>

Five underground shafts have been proposed to house the reversible pump turbine units required for power generation and pumping. Each powerhouse shaft will be about 29 m finished diameter required to accommodate the PTG units and around 108.5 m height. Each shaft is spaced at a clear distance of about 60 m.



Preliminary supports are required during construction & shafts will be suitably lined with concrete. The finished grade level at powerhouse area is fixed at RL 309.00 m, 3 m above the full reservoir level of proposed lower reservoir. The superstructure covers all the shafts and size of building is 52 m (W) x 280 m (L). The plan and typical cross section of powerhouse are indicated in Exhibits - 14 and 15.

9.5.7 <u>Tailrace Tunnel</u>



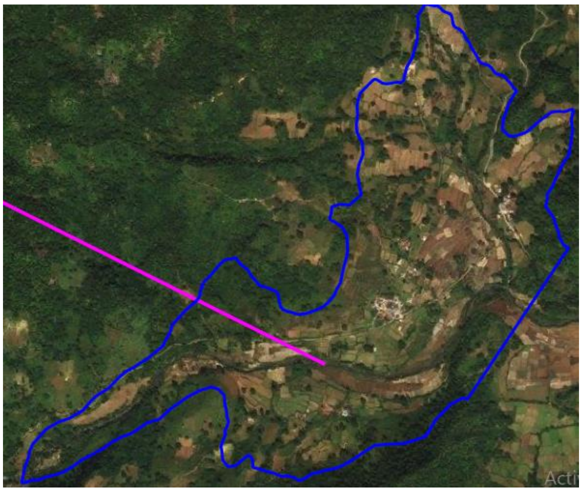
Water after power generation, is let back into the lower reservoir through a tailrace tunnel of about 5300 m long. It will be of horse shoe shaped and proposed to provide concrete lining for the entire length of tunnel. A finished diameter of 8.0 m is adopted for the tailrace tunnel, similar to HRT with a design flow velocity of about 4.54 m/s. Longitudinal section of along the tailrace tunnel indicating the ground profile and suggested tunnel grade is shown in Exhibit - 12 and cross section details are shown in Exhibit - 13. A roller gate under bonnet is proposed for isolation of tailrace as shown in Exhibit - 15. An additional space/room is proposed downstream of PTG units (above draft tube) to facilitate erection of gates and hydraulic hoist/cylinders. A separate access tunnel is proposed from service bay level to facilitate operation of bonnet gates during O&M stage.

Based on the preliminary geological inferences, it is most likely that the majority of the tunnel alignment will pass through good to fair rock mass, the tunnel will be free from weak zones like shear zones, faults etc. Considering the type of rock mass, preliminary supports in the form of shotcrete and rock bolts are envisaged during construction. However, the entire tunnel design including supports will be further reviewed during DPR stage based on detailed investigations and lab test results.

9.5.8 *Lower Intake*

The lower intake is proposed to draw water during pumping mode to pump water from lower reservoir to upper reservoir. Based on submergence requirement and considering a margin of 2 m, the top of bell-mouth of vertical intake is planned at RL 267.00 m. Circular intake structure will be provided with twelve (12) nos. of trashrack bays, each of size 3.9 m (W) x 7.0 m (H), so as to prevent entry of trash along with intake gates for isolation of tailrace tunnel. The hydraulic design of lower intake is given in Annexure - 7.2 and details of lower intake are shown in in Exhibit- 12.

9.5.9 *Lower Dam/Reservoir*



Lower dam will be located across Boduru Gedda river near Kurukutti (Nerellivalasa) village. The possibility for further optimization of lower dam/reservoir was reviewed. Based on review of topographical data, it was observed that the cost of lower reservoir for Kurukutti PSP could be further reduced if the additional storage required for operation of proposed Karrivalasa PSP can be accommodated at the same location. With this, the cost of lower reservoir can be apportioned between two projects and thereby reducing the project cost and land requirement. Hence, it is suggested to consider common lower dam/reservoir for both Kurukutti and Karrivalasa PSP's. Accordingly, the revised FRL required for meeting storage requirement of both projects has been determined using elevation-area-capacity data and found to be RL 306.00 m. The finalized parameters of lower dam/reservoir are as given below:

a) FRL - RL 306.00 m
b) MDDL - RL 281.00 m
c) MWL - RL 307.90 m
d) Dam height - 62 m (above deepest RBL)

e) Length of dam - 740 m

f) Submergence - 160 Ha

g) Gross storage - 38.7 Mm^3

h) Spillway - Gated, 5 Radial Gates, each of size 5 m (W) x 7 m (H)

9.6 Hydro-Mechanical Equipment

The following hydro-mechanical equipment are proposed for Kurukutti PSP:

a) Gates, stop-logs and trash rack at upper intake
b) Trash racks at upper intake
c) Intake and Stop-log gates (HRT)
d) Steel liner for pressure shaft
e) Surge shaft gate
f) Draft tube gates
g) Intake and stop log Gates (TRT)
h) Trash racks at Lower intake
i) Radial gate at bottom outlet of Lower dam

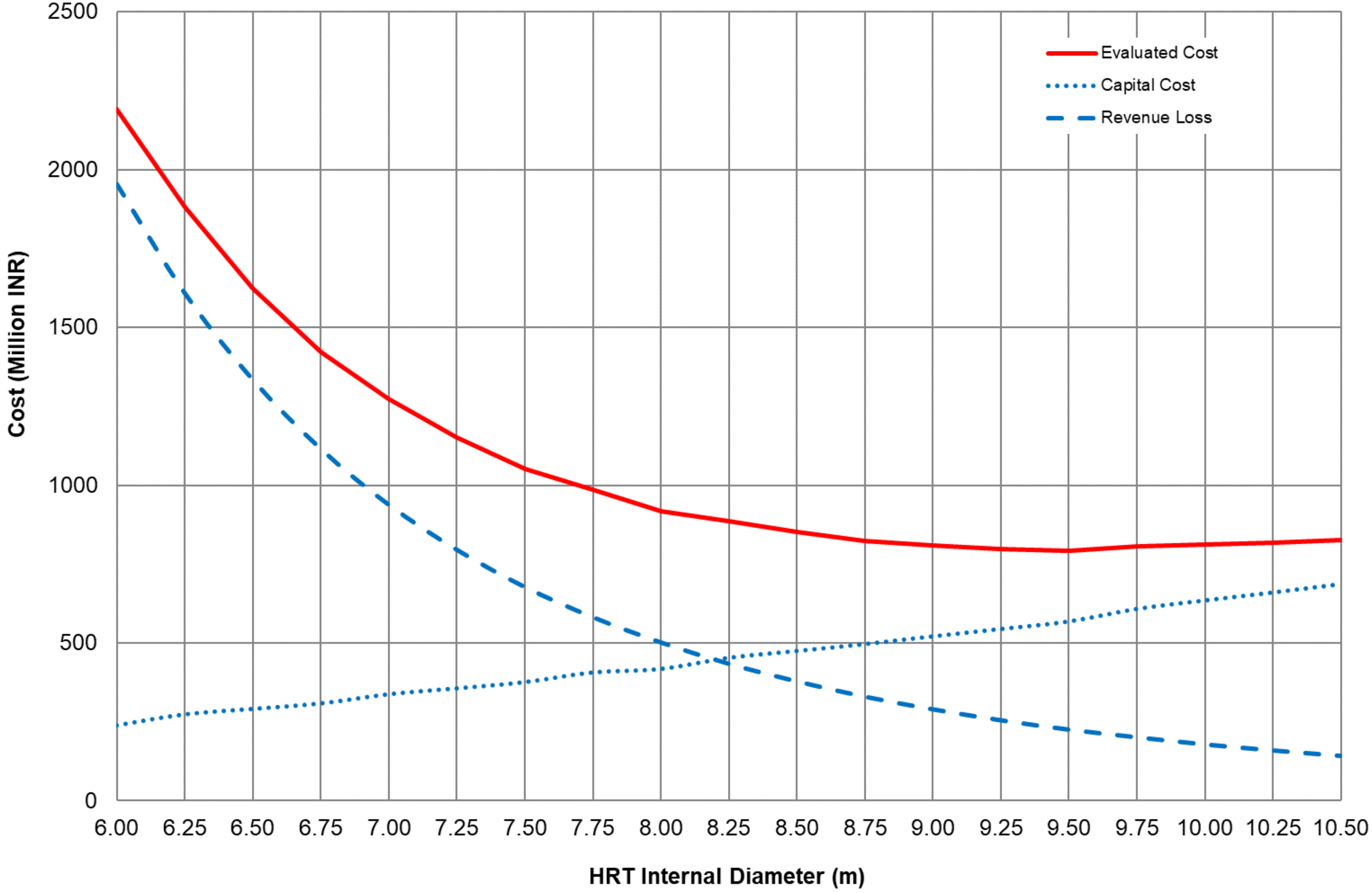
Annexure - 9.1

Economical Diameter of HRT & Pressure Shaft

A. Headrace Tunnel

Basic Data & Assumptions					
Rated Discharge	241.00	m^3/s	Discount Rate	10	%
RCC lined Section Length =	1010	m	Discount Period	40	years
Shotcrete lined section length =	0.00	m	Present Worth Factor	9.78	
Total length of tunnel	1010	m	Energy Rate	4.00	Rs./kWh
Design Discharge =	241.00	m^3/s			
RATES:					
Excavation	2100	Rs./m^3			
Outer Concrete Lining	6115	Rs./m^3			
Shotcreting	1480	Rs./m^2			
Reinforcement Steel	77200	Rs./tonne			
Steel supports	97305	Rs./tonne			
Rock Bolts	1140	Rs. / m			
Drilling for grouting/drainage	455	Rs. / m			

													Million Indian Rupees (INR)											
Sl. No.	Tunnel size (Horse-shoe Shaped) (m)	Max. Vel. (m/s)	Tunnel C/s Area (A) (m2)	Wetted Perimeter (P) (m)	Hyd Radius R= A/P (m)	Excav. Qty (m^3)	Concrete Lining Qty (m^3)	Shotcreting Qty (m^2)	Reinf Qty (MT)	Steel Support (MT)	RB/RA	Drilling for grouting	Excav. Cost	Concrete Cost	Shotcreting Cost	Steel Support and Reinf. Cost	RB/RA	Drilling for grouting	Total Tunnel Civil Cost	Annual Energy Loss Mu	Annual Energy Loss M. INR	Capitalised Energy Loss M. INR	Total Evaluated Cost M. INR	Differential Evaluated cost M. INR
1	6.00	8.1	29.9	19.6	1.5	41000	10350	18800	90	225	21100	16900	86	63	28	29	24	8	238	50.0	200	1954	2192	1399
2	6.25	7.4	32.4	20.4	1.6	48800	11200	19550	100	295	24680	18300	102	68	29	36	28	8	273	41.1	164	1608	1881	1089
3	6.50	6.9	35.0	21.2	1.6	52600	11950	20350	105	310	25610	19775	110	73	30	38	29	9	290	34.1	136	1333	1623	831
4	6.75	6.4	37.8	22.1	1.7	56550	12750	21100	110	320	26560	21275	119	78	31	40	30	10	308	28.5	114	1114	1422	630
5	7.00	5.9	40.6	22.9	1.8	60750	13650	21850	120	400	30570	22850	128	83	32	48	35	10	337	24.0	96	937	1274	482
6	7.25	5.5	43.6	23.7	1.8	65000	14500	22650	125	410	31600	24450	137	89	34	50	36	11	355	20.3	81	794	1150	358
7	7.50	5.2	46.6	24.5	1.9	69300	15400	23400	135	425	32650	26150	146	94	35	52	37	12	375	17.3	69	676	1051	259
8	7.75	4.8	49.8	25.3	2.0	73900	15800	24200	135	545	37100	27850	155	97	36	63	42	13	406	14.8	59	581	987	194
9	8.00	4.5	53.1	26.1	2.0	77600	16300	24800	140	555	34525	29550	163	100	37	65	39	13	417	12.8	51	501	918	125
10	8.25	4.3	56.4	27.0	2.1	83350	18300	25700	160	575	39375	31475	175	112	38	68	45	14	452	11.1	44	433	885	93
11	8.50	4.0	59.9	27.8	2.2	88250	19250	26450	165	595	40525	33375	185	118	39	71	46	15	474	9.6	39	377	851	59
12	8.75	3.8	63.5	28.6	2.2	93300	20250	27250	175	605	41675	35325	196	124	40	72	48	16	496	8.4	34	329	825	32
13	9.00	3.6	67.2	29.4	2.3	98700	21450	28000	185	625	42800	37350	207	131	41	75	49	17	521	7.4	30	289	809	17
14	9.25	3.4	71.0	30.2	2.3	104000	22450	28800	195	645	43950	39450	218	137	43	78	50	18	544	6.5	26	254	798	6
15	9.50	3.2	74.8	31.0	2.4	109500	23550	29550	205	660	45100	41525	230	144	44	80	51	19	568	5.7	23	224	792	BASE
16	9.75	3.1	78.8	31.9	2.5	115350	24800	30300	215	770	50500	43700	242	152	45	92	58	20	608	5.1	20	200	808	15
17	10.00	2.9	82.9	32.7	2.5	121250	26100	31100	225	795	51800	46000	255	160	46	95	59	21	635	4.5	18	177	812	20
18	10.25	2.8	87.1	33.5	2.6	127200	27250	31850	235	810	53000	48200	267	167	47	97	60	22	660	4.0	16	158	818	26
19	10.50	2.6	91.4	34.3	2.7	133300	28450	32600	245	830	54250	50550	280	174	48	100	62	23	687	3.6	14	141	827	35



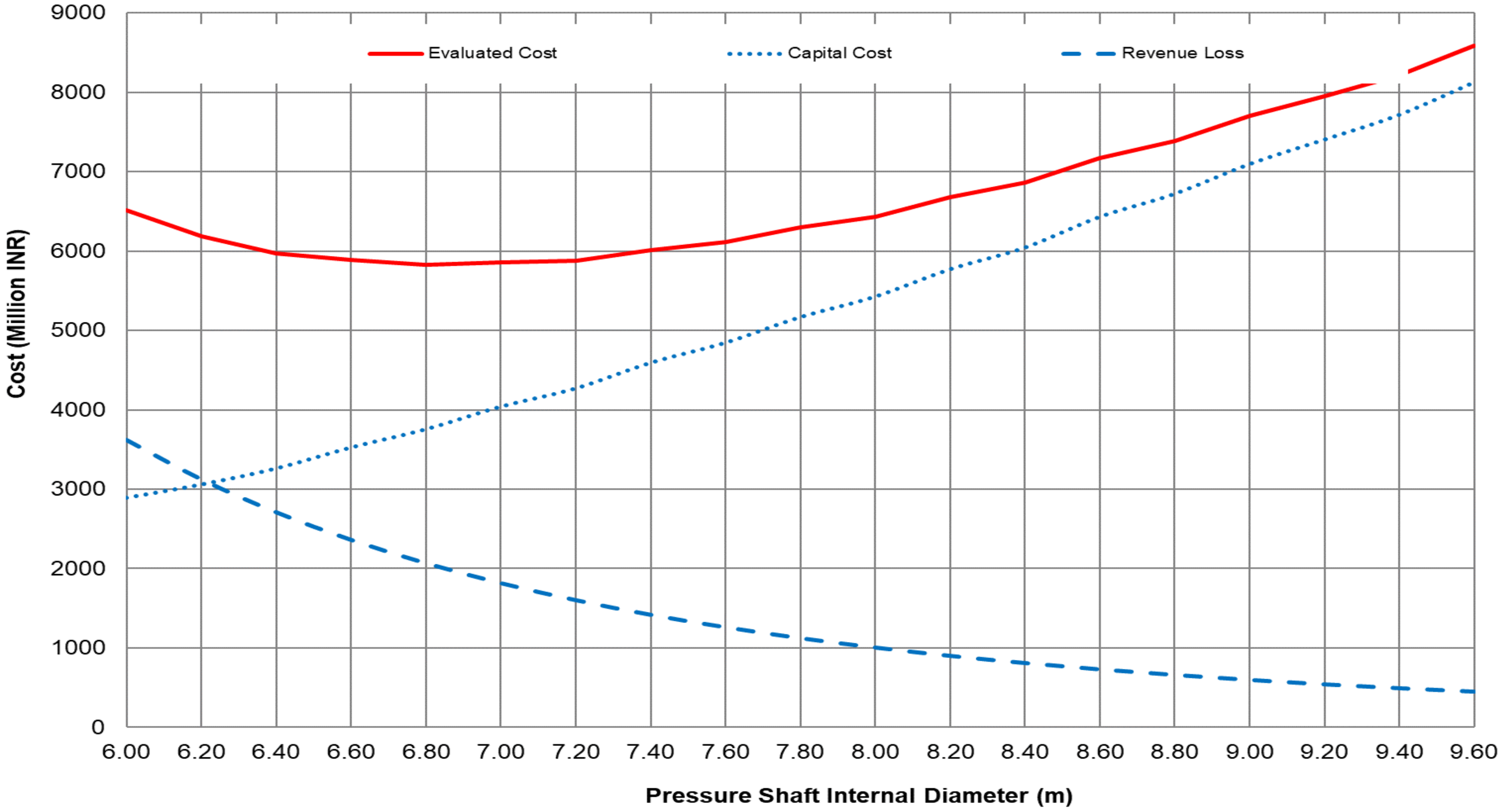
2500
2000
1500
1000
500
0
Cost (Million INR)
6.00
6.25
6.50
6.75
7.00
7.25
7.50
7.75
8.00
8.25
8.50
8.75
9.00
9.25
9.50
9.75
10.00
10.25
10.50
HRT Internal Diameter (m)
Evaluated Cost
Capital Cost
Revenue Loss

B. Pressure Shaft

Basic Data & Assumptions					
Rated Discharge	241.00	m^3/s	Discount Rate	10	%
RCC lined Section Length =	1800	m	Discount Period	40	years
Shotcrete lined section length =	0	m	Present Worth Factor	9.78	
Total length of pressure shaft =	1800	m	Energy Rate	4.00	Rs./kWh
Design Discharge =	241.00	m^3/s			
RATES:					
Tunnel Excavation	2100	Rs./m^3			
Shaft Excavation	2840	Rs./m^3			
Concrete Backfilling	6115	Rs./m^3			
Shotcreting	1480	Rs./m^2			
Reinforcement Steel	77200	Rs./tonne			
Steel supports	97305	Rs./tonne			
Rock Bolts	1140	Rs. / m			
Drilling for grouting/drainage	455	Rs. / m			
Steel ferrule	125000	Rs./tonne			

Sl. No.	PS size (Circular Shaped) (m)	Max. Vel. (m/s)	Tunnel C/s Area (A) (m2)	Wetted Perimeter (P) (m)	Hyd Radius R= A/P (m)	Excav. Qty (m^3)	Shaft Qty	Concrete Lining Qty (m^3)	Shotcreting Qty (m^2)	Reinf Qty (MT)	Steel Support (MT)	RB/RA (RM)	Drilling for grouting (RM)	Steel Liner (MT)
1	6.00	8.5	28.3	18.9	1.5	94220	18500	26920	31540	130	370	31050	22670	18690
2	6.20	8.0	30.2	19.5	1.5	87710	19820	24810	32670	130	490	36140	22810	20060
3	6.40	7.5	32.2	20.1	1.6	93540	21130	25730	33770	140	510	37300	24310	21460
4	6.60	7.0	34.2	20.7	1.6	99640	22510	26640	34880	140	530	38510	25880	23350
5	6.80	6.6	36.3	21.4	1.7	106070	23960	27570	36000	150	650	39730	27480	24870
6	7.00	6.3	38.5	22.0	1.7	112560	25420	28480	37110	150	670	45460	29150	26880
7	7.20	5.9	40.7	22.6	1.8	119200	26910	29400	38210	150	690	46790	30850	28480
8	7.40	5.6	43.0	23.3	1.8	126280	28520	30320	39350	160	870	48150	32620	30690
9	7.60	5.3	45.4	23.9	1.9	133270	30080	31230	40450	160	900	54390	34410	32410
10	7.80	5.0	47.8	24.5	1.9	140470	31700	32160	41550	170	920	55850	36260	34740
11	8.00	4.8	50.3	25.1	2.0	148060	33420	33080	42670	170	940	57330	38330	36540
12	8.20	4.6	52.8	25.8	2.0	155720	35140	33990	43780	180	970	58780	40110	39030
13	8.40	4.3	55.4	26.4	2.1	163490	36880	34900	44870	180	990	60200	42120	40950
14	8.60	4.1	58.1	27.0	2.1	171770	38760	35830	46010	190	1160	67360	44170	43600
15	8.80	4.0	60.8	27.6	2.2	179880	40580	36750	47110	190	1190	68950	46270	45640
16	9.00	3.8	63.6	28.3	2.2	188210	42450	37660	48210	190	1210	70490	48420	48370
17	9.20	3.6	66.5	28.9	2.3	196750	44360	38590	49310	200	1240	72070	50600	50540
18	9.40	3.5	69.4	29.5	2.3	205440	46310	39500	50410	210	1270	73600	52820	52740
19	9.60	3.3	72.4	30.2	2.4	214450	48330	40410	51520	210	1300	75220	55300	55710

Sl. No.	Million Indian Rupees (INR)													
	Excav. Cost	Shaft Cost	Concrete Cost	Shotcreting Cost	Steel Support and Reinf. Cost	RB/RA	Drilling for grouting	Steel Liner Cost	Total Tunnel Civil Cost	Annual Energy Loss Mu	Annual Energy Loss M. INR	Capitalised Energy Loss M. INR	Total Evaluated Cost M. INR	Differential Evaluated cost M. INR
1	198	53	165	47	46	35	10	2336	2890	92.5	370	3619	6509	686
2	184	56	152	48	58	41	10	2508	3057	79.9	319	3124	6181	359
3	196	60	157	50	60	43	11	2683	3260	69.3	277	2710	5970	148
4	209	64	163	52	62	44	12	2919	3525	60.4	242	2362	5887	64
5	223	68	169	53	75	45	13	3109	3754	52.9	212	2069	5823	BASE
6	236	72	174	55	77	52	13	3360	4040	46.5	186	1818	5858	35
7	250	76	180	57	79	53	14	3560	4269	41.0	164	1605	5874	51
8	265	81	185	58	97	55	15	3836	4593	36.3	145	1420	6013	190
9	280	85	191	60	100	62	16	4051	4845	32.3	129	1264	6109	286
10	295	90	197	61	103	64	16	4343	5168	28.8	115	1126	6295	472
11	311	95	202	63	105	65	17	4568	5426	25.8	103	1008	6434	612
12	327	100	208	65	108	67	18	4879	5772	23.1	92	904	6676	853
13	343	105	213	66	110	69	19	5119	6045	20.8	83	814	6858	1035
14	361	110	219	68	128	77	20	5450	6432	18.8	75	734	7166	1343
15	378	115	225	70	130	79	21	5705	6723	17.0	68	664	7387	1564
16	395	121	230	71	132	80	22	6046	7098	15.4	62	601	7700	1877
17	413	126	236	73	136	82	23	6318	7407	14.0	56	546	7953	2130
18	431	132	242	75	140	84	24	6593	7719	12.7	51	497	8217	2394
19	450	137	247	76	143	86	25	6964	8128	11.6	46	454	8582	2759



Evaluated Cost
Capital Cost
Revenue Loss
Cost (Million INR)
0
1000
2000
3000
4000
5000
6000
7000
8000
9000
6.00
6.20
6.40
6.60
6.80
7.00
7.20
7.40
7.60
7.80
8.00
8.20
8.40
8.60
8.80
9.00
9.20
9.40
9.60
Pressure Shaft Internal Diameter (m)

Annexure - 9.2

Preliminary Sizing of Surge Shaft & Estimation of Maximum Upsurge and Down surge

Basic Data & Assumptions

Type of Surge Shaft	=	Restricted Orifice	
Design discharge, Q	=	241.00	m^3/s
Diameter of pressure shaft, d	=	6.8	m
Diameter of tunnel, D	=	8.0	m
Length of tunnel, L	=	1010	m
Value of rugosity coefficient, n	=	0.014	0.012
Orifice discharge coefficient, C_d	=	0.6	
Full Reservoir Level (FRL)	=	899.0	RL in m
Min. Drawdown Level (MDDL)	=	861.0	RL in m

Computations

<u>Area of Surge Tank (Thoma Criteria)</u>

Area of tunnel, A_t	=	53.08	m^2
Perimeter of tunnel, P_t	=	26.14	m
Velocity in HRT, V_1	=	4.54	m/s
<u>Hydraulic Losses</u>			
For medium rugosity (n = 0.014)	=	2.80	m
For minimum rugosity (n = 0.012)	=	2.37	m
$\beta V_1^2{}_{max}$	=	2.37	m
Design head loss, H_L	=	2.37	m
Net Head on Turbine CL, Ho	=	569	m
Area of Surge Shaft, A_{th}	=	41.72	m^2
Factor of Safety	=	1.6	
Required Area	=	66.75	m^2
Diameter of Surge Shaft	=	9.22	m
Adopted Diameter	=	**10.00**	**m**
Design Area of Surge Shaft	=	**78.54**	**m^2**

<u>Area of Orifice</u>

Surge height corresponding to change in discharge neglecting frction and orifice losses, Z*	=	37.87	m
For medium rugosity (n = 0.014)			
Range of Orifice head loss, h_{or} (m)	=	**27.48**	**28.88**
For minimum rugosity (n = 0.012)			
Range of Orifice head loss, h_{or} (m)	=	**27.38**	**28.56**
Adopted loss across Orifice, H_{or}	=	**27.38**	m
Area of Orifice, A_{or}	=	17.33	m^2
Diameter, D_{or}=	=	4.70	m
Adopted Orifice Diameter	=	**4.70**	**m**

Maximum Upsurge for Total Load Rejection

Coefficient of hydraulic losses, β	=	0.12	
Area of pressure shaft, A_p	=	36.32	m^2
Velocity of flow, V_2	=	6.64	m/s
Coefficient of resistance for orifice, η	=	6.24	
$\beta / (\beta + \eta)$	=	0.02	
$((\beta + \eta) V^2) / Z^*$	=	3.46	
Z_{max} / Z^* (Read from graph)	=	0.30	
Maximum upsurge, Zmax.	=	11.36	m
Maximum water level in the Surge tank	=	910.38	RL in m
Top of surge tank	=	911.88	RL in m
	say	**912.00**	**RL in m**

Maximum Downsurge for Load Acceptance

$P_o = h_f/Z_*$	=	0.06	
$Z_{down}/Z^* = -1 + 2*P_o$	=	-0.87	
Maximum downsurge, Zdown.	=	-33.13	m
Minimum water level in Surge tank	=	**827.89**	**RL in m**

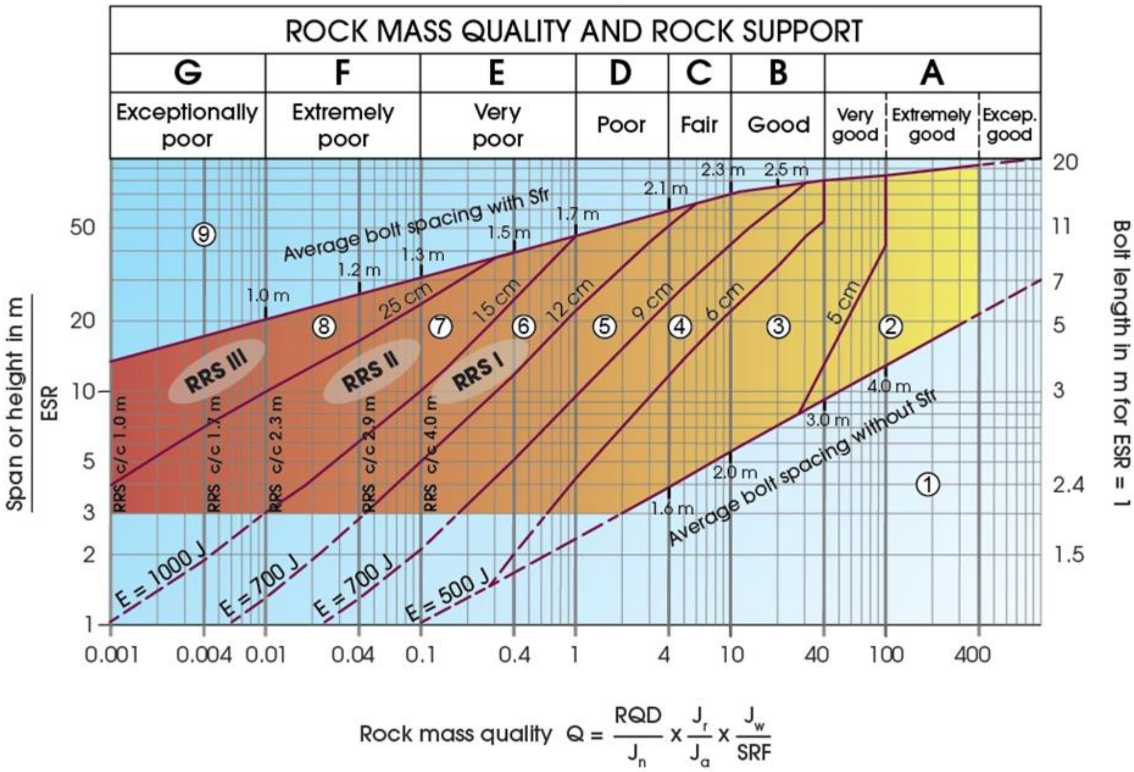
Annexure - 9.3

Preliminary Design of Support Systems for

Headrace Tunnel and Pressure Shaft

Tunnel Support Systems

Tunnel support requirements are primarily dependent upon the site conditions encountered. However, in the present case, for feasibility study, minimum required support for the headrace tunnel for given opening size of 8 m diameter is decided based on Empirical method i.e. Barton's support category chart on tunneling quality index, Q (after Barton, 2014) as shown below.



The length and spacing of rock bolts and shotcrete required for the support is obtained from this empirical approach. The considered length of rock bolts shall be further verified during DPR stage using Numerical Analysis.

Excavation support classes have been designated from Class-I to Class-V based on Barton's rock mass classification. The proposed support system for headrace tunnel (8 m diameter) in the form of shotcrete, rock bolts and steel ribs to various support classes are briefed in the table below:

Support Class	Rock Mass Classification (Q)	Q Values	Tentative Rock Support
Class-I	Very Good	Q = 40 to 100	25 mm dia, 5 m long Rock Bolts (Spot Bolting)
Class-II	Good	Q = 10 to 40	25 mm dia, 5 m long Rock Bolts @ 2 m c/c 50 mm thick shotcrete at crown
Class-III	Fair	Q = 4 to 10	25 mm dia, 5 m long Rock Bolts @ 2 m c/c 50 mm thick shotcrete at crown
Class-IV	Poor	Q = 1 to 4	25 mm dia, 5 m long Rock Anchors @ 1.5 m c/c 100 mm thick shotcrete Steel ribs ISMB 250 @ 750 mm c/c
Class-V	Very Poor	Q = 0.1 to 1	25 mm dia, 5 m long Rock Anchors @ 1.5 m c/c 100 mm thick shotcrete Steel ribs ISMB 250 @ 600 mm c/c

The proposed support system for pressure shaft (6.8 m dia) in the form of shotcrete, rock bolts and steel ribs to various support classes are briefed in the table below:

Support Class	Rock Mass Classification (Q)	Q Values	Tentative Rock Support
Class-I	Very Good	Q = 40 to 100	25 mm dia, 5 m long Rock Bolts (Spot Bolting)
Class-II	Good	Q = 10 to 40	25 mm dia, 5 m long Rock Bolts @ 2 m c/c 50 mm thick shotcrete at crown
Class-III	Fair	Q = 4 to 10	25 mm dia, 5 m long Rock Bolts @ 2 m c/c 50 mm thick shotcrete at crown
Class-IV	Poor	Q = 1 to 4	25 mm dia, 5 m long Rock Anchors @ 1.5 m c/c 100 mm thick shotcrete Steel ribs ISMB 250 @ 750 mm c/c
Class-V	Very Poor	Q = 0.1 to 1	25 mm dia, 5 m long Rock Anchors @ 1.5 m c/c 100 mm thick shotcrete Steel ribs ISMB 250 @ 600 mm c/c

Chapter - X
Electrical and Mechanical Systems

10.1 Mechanical Equipment

10.1.1 *General*

The capacity of proposed Kurukutti pumped storage project is 1200 MW. The rated head during operation in turbine and pump mode are 569 m & 603 m respectively. Each unit, inlet valve and all associated auxiliary systems are envisaged to be housed in a vertical shaft. Access tunnels would be provided connecting the vertical shafts. The general arrangement of generating equipment is enclosed as Exhibit - 14.

10.1.2 *Unit selection*

a) Type of Units

With the envisaged locations of upper and lower reservoirs, the rated head values during generation and pumping operations are 569 m & 603 m respectively. The head variation during generation mode operation is from 598 m to 535 m and that during pumping operation is from 569 m to 632 m. The availability of reversible units for the above head values were checked and same are considered based on the response from the suppliers of Reversible units.

b) Number of Units

For achieving the proposed capacity of 1200 MW, Option of 5 units of 240 MW capacity each was studied. The speed works out to be 428.6 rpm and the runner diameter is approximately 4.7 m. Further, unit capacity of 300 MW was also checked and found that the diameter works out to be about 5.4 m (greater than 5 m). In the absence of transportation logistics, The runner Diameter is restricted to 5.0 diameter for this study. Option of suitability of units of 300 MW capacity could be further reviewed with respect to machine availability and transportation limitations during Detailed Project report stage.

Option of providing two smaller units instead of one larger unit will also be reviewed with respect to load demand curve and the availability of pumping power vis-à-vis provision of variable speed units for increasing the plant availability and operational flexibility.

For this report, 5 Nos of 240 MW capacity each reversible units are considered.

c) Equipment Type

Two types of Reversible type pump turbine machines are available viz. Constant speed where the machines operate at a fixed speed and Variable speed machines. Selection of type and configuration of units is critical for the proposed Kurukutti pumped storage project, which is being planned as energy/power storage systems for large scale renewable energy projects (Wind & Solar) thar are being implemented in the State of Andhra Pradesh and at All-India level.

A detailed techno-economic evaluation of various aspects of fixed speed and variable speed units has been made and a comparative statement is furnished in Table - 10.1.

Table - 10.1: Fixed vs Variable Speed PTG Units

Sl. No.	Description	Fixed Speed Units	Variable Speed Units
I	**Technical Aspects**		
1.	Operation philosophy	Operates at a fixed speed in both pumping and generating modes	Rotational speed of motor/generator is adjustable
2.	Operating Head Range	80% to 100% (Operation at wider head ranges will result in high cavitation levels or excessive unit submergence)	70% to 100% (Allows operations at wider head ranges without cavitation & requirement of higher unit setting)
3.	Power (Generation mode)	50% to 100%	30% to 100%
4.	Power (Pumping mode)	100%	70% to 100%
5.	Generating efficiency	Base (units cannot operate at peak efficiency during part load)	(+) 1% to 1.5% (Units are operated at slower speed at part load to improve part load and peak efficiency)
6.	Pump Start	Relatively Difficult & Slow (can be difficult to obtain the large block of power necessary for pump starting)	Relatively Easy & Fast (can be started at lower speed, reducing the power requirement to bring pump on line)
7.	Frequency regulation	Not feasible (can be provided only in generation mode, by controlling flow rate through Wicket gates)	Feasible (by accommodating variable power supply in both generation & pumping modes)
8.	Operational flexibility	Relatively Less (units cannot adjust to power fluctuations in	High (units can adopt faster to power fluctuations, thereby

Sl. No.	Description	Fixed Speed Units	Variable Speed Units
		pumping mode and thereby increases no. of machine start & stops)	reducing number of machine start and stops)
9.	Suitability against varying power sources like Solar / Wind	Relatively Less (units cannot be operated under pumping mode to match with varying power output from renewable energy sources)	More (units can even be operated upto 30% reduced power output)
10.	Plant Load Factor	Relatively Less	More
II	**Financial Aspects**		
11.	Equipment cost	Base	(+) 30%
12.	Civil works cost	Base	(+) 15% - 20% (additional costs due to physically larger units and requirement of electronic equipment & additional transformers)

The source of off-peak power required for pumping is envisaged from the renewable energy projects like Solar & Wind power plants. As explained in Chapter - II, the total share of renewables in the State of Andhra Pradesh and national power grid is expected to be greater than 50% of overall capacity within next 5-10 years. Due to the varying nature of renewable energy sources, large fluctuations in availability of off-peak power can be expected.

With Provision of only constant speed units, the units cannot be operated in pump mode unless the rated power requirement is available (since fixed speed units cannot operate at lesser power output). When the available power is less than the rated power, complete available power cannot be utilized. Thus, provision of fixed speed units may cause the units/plant to remain idle during periods of low availability of off-peak power (especially during low output from solar/wind plants) and reduce the overall plant load factor and sub-optimal utilization of PSP.

On the other hand, a variable speed unit can be operated with minimum power of 70% of the rated power requirement. With provision of variable speed units, available energy can be utilized efficiently and there will be improvement in the overall plant load factor since most of the off-peak power can be utilized for pumping and the objective of energy storage can be met to a maximum extent. In addition, annual energy generation can increase by about 2% to 3% due to capability of variable speed units to operate at increased efficiency while operating at part loads.

Constant / fixed speed units are cost efficient and the variable speed units offer better utility of the power. Combination of constant and variable speed units ensure better utilization of the available energy and optimizes overall capital cost of project. To ensure cost benefit and the flexibility in operation of the machines, two units are considered with Variable speed and three of Fixed speed type.

The possibilities of further reducing the number of variable speed units will be reviewed during DPR stage by evaluating the option of providing required power modulation through "Hydraulic Short Circuit" concept, which has been implemented for the 450 MW (3 x 150 MW) Kops II pumped storage plant in Austria, which is operational since November 2008.

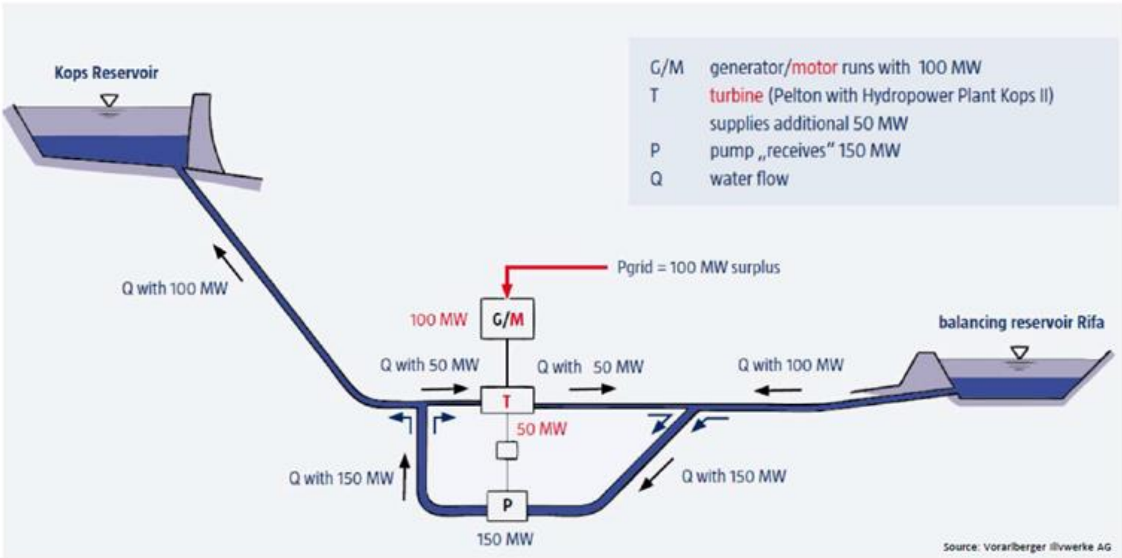


Figure - 10.1: Hydraulic Short Circuit (Definition Sketch)

10.1.3 *Brief Particulars of Equipment*

Reversible Units

The power plant shall be equipped with Five (5) vertical-axis reversible-type hydroelectric units composed each of a generator-motor and a pump-turbine allowing two rotational directions of the rotating part. In one direction, by virtue of the energy supplied by the electrical network, the electrical machine operates as a synchronous motor and drives the hydraulic machine in pumping mode allowing it to pump the water from the lower reservoir to the upper reservoir. In the opposite direction, the hydraulic machine operates as turbine with water being supplied from the upper reservoir and drives the electrical machine as a synchronous generator enabling it to generate electric power.

Reversible units shall be made up of a single stage Francis pump-turbine and a synchronous generator-motor. Three units shall be of fixed speed configuration and two units of variable speed. The rotor of the motor-generator and runner of reversible pump-turbine shall be connected by an intermediary shaft. The whole rotating part shall be guided in rotation by three bearings (two bearings placed on either side of the generator-motor rotor and a bearing fixed just above the pump-turbine) and one generator bearing shall be guide cum thrust bearing, capable of withstanding both weight of the rotating part and hydraulic axial thrust on the runner.

The regulation of the pump-turbine distributor position shall be ensured by an electronic, programmable logic, state-of-the-art speed-governor with proportional, integral and derivative actions. In generating mode, this speed governor shall operate the unit in primary regulation, either of generator frequency-power type or turbine frequency-opening type. In pump mode, the governor shall operate the position of the distributor according to the head and the network frequency to obtain maximum efficiency or flow stability.

The estimated specific speed of the pump - turbine is about 89.6 & 22.3 (In rpm metric hp & MWC Unit) in generation and pumping mode respectively. The turbine would be suitably rated to provide 240 MW at generator terminals at rated head of 569 m. The speed of turbine is estimated to be 428.6 RPM.

To prevent excessive cavitation in Pump Turbine Unit, submergence requirements are to be ensured. For reversible units, submergence requirement during pumping operation is more critical and hence the unit centerline is worked out for pumping mode operation. Accordingly, the center of pump - turbine runner has been set at RL 232.00, 49 m below the minimum TWL. The runner diameter would be about 4.7 m.

Units will also be designed to be operated in Condenser mode to compensate the Grid instability.

10.1.4 *EOT Crane*

The heaviest equipment which the powerhouse cranes are required to be handled during erection and subsequently during maintenance is the generator rotor. The weight of the generator rotor has been estimated to be about 400 tonnes. Considering the weight of

Equalizing / lifting beam and the crane margin, It is proposed to provide two EOT cranes of 275/80 tonnes capacity each. These cranes would operate in Tandem.

10.1.5 *Auxiliary Equipment and Systems for the Powerhouse*

Following Auxiliary systems would be provided:

- Cooling water system
- Drainage & Dewatering System
- HP / LP Compressed Air system
- Air Conditioning and ventilation system
- Oil Handling system
- Fire protection system
- Workshop
- Elevators

10.2 Electrical Equipment

10.2.1 *General*

It is proposed to install three (3) nos. 240 MW synchronous machines for fixed speed type and two (2) nos. 240 MW asynchronous machines (DFIM-Doubly Fed Induction Machine) for Variable speed application for Kurukutti Pump Storage scheme. Synchronous / DFIM machines are operated as motor to pump water from the lower reservoir to the upper reservoir and as synchronous/DFIM generators to produce electrical power by using the energy of the water which flows from upper reservoir to the lower reservoir.

a) The voltage level of generator/motor is considered as 15kV. However, this has to be verified with the actual value selected by the vendor for this rating.
b) The synchronous/DFIM machines will be connected to 400kV Gas Insulated Substation (GIS) through step-up transformers. During the generating mode these transformers will step up the voltage to 400kV from the generation voltage of 15kV for power evacuation and during the pumping mode these transformers will back-fed these synchronous/DFIM machines to work as pump motor.

10.2.2 *Generator*

The Hydro Generator/ Motor will be salient pole, vertical shaft directly coupled to the turbine. The manufacturer based on economics of machine design will select the rated generator voltage.

The generator/motor will be complete with excitation system, neutral grounding arrangement, phase and neutral side C.T.s, RTDs, bearings with bearing oil level and temperature monitoring / protection system, brake and jack assembly etc.

10.2.3 *Excitation System*

The excitation system will be solid state, static excitation system for the generator/ motor exciter with voltage regulator function.

The Automatic voltage regulator (AVR) function of modern solid-state excitation system is an integral part of the system and will use digital control elements with microprocessor-based control. The voltage regulator function will provide automatic and manual control of generator output voltage over a range of at least ±10%.

The excitation power will be tapped from generator busduct through excitation transformer. The excitation transformers will be dry type with cast resin insulation.

10.2.4 *Generator Braking*

Mechanical braking, using pressurized air will be used for the quick shut down of the machine.
The DFIM machine in Generator mode, regenerative braking will be applied as soon as Generator Circuit breaker is open. This will be done by using Static frequency converter which will use energy stored in T-G to feed back into the grid. Regenerative braking will be done till speed drops to around 20% of rated speed at which mechanical brakes will be applied. For synchronous machine, dynamic braking will be used.

10.2.5 *Starting Method*

Static Frequency Converter (SFC) based starting will be used for Conventional fixed speed system. The SFC used will be of High-Voltage large capacity thyristor converters designed for large capacity motor starters. The thyristor starter comprises of a source side converter, a machine side converter, AC reactors, DC reactors & a control & protection system.

Voltage source inverter (VSI) based starting will be used for Variable speed driven system. The VSI used will be of High-Voltage large capacity IGBT converters designed for large capacity motor starters. The starter comprises of voltage source inverter, VSI transformer, filters, control & protection system.

Synchronous machine: Two nos. of SFC are being considered for starting of three units which can selectively start the generator motors and it will be by-passed after starting.

DFIM machine: The DFIM rotor will be connected to a Voltage source inverter (VSI) supplying a three-phase sine wave at a desired slip frequency. The VSI will be used for motor start.

10.2.6 *Generator/ Motor- Transformer Connection*

The connection between of generator, generator circuit breaker, generator transformer and unit transformers will be achieved by isolated phase type bus-duct. Bus duct will be provided with required tap offs for LAVT, Excitation transformer, SFC circuit etc. The Generator circuit-breaker will be of SF6-gas type.

10.2.7 *Phase reversing Switch Disconnectors*

Phase reversing disconnectors is used whenever the system is operated in pumping mode for the motor operation. The equipment consists of two isolators kept in parallel with each other and one isolator with reverse phase sequence.

The main differences between the generating and pumping operating modes are changes in direction of the machine rotation and change of direction (i.e. sign) of the active power flow. This rotation direction change is achieved by so-called phase reversal disconnect switches. These disconnect switches simply swap two phases in pumping mode in order to reverse the phase sequence to the machine.

10.2.8 *Generator Step up Transformer*

The generator step-up transformer will be oil filled, either three nos. single phase two winding rated approx.98 MVA,15kV/420/√3 kV or one no. 3 phase transformer rated approx.294 MVA, 15 kV/420 kV per unit. The transformers will be complete with all accessories and sufficient mineral oil for first filling. The GT LV connection to generator through isolated phase type bus duct while HV will be connected with Gas insulated Busduct (GIB).

The vector group of GT will be Ynd1 with HV neutral connected solidly to ground. GTs will be provided with off circuit tap changer with taps of +5% to -5% in steps of 2.5%.

Transformers will be protected with fire wall and water spray system. One soak pit will be provided below each transformer that will be connected to common burnt oil pit. Transformers will be installed on rail tracks.

10.2.9 *400 kV Gas Insulated Substation & Cables*

Generator transformers will be connected to the 400 kV Gas insulated substation through GIB conductor. GIS will be of double bus switching scheme consisting of five incoming circuits from transformer bays, one bus shunt reactor bay, two outgoing line bays & buscouplers.

GIS substation will consist of the following:

a) 400 kV Circuit breakers.
b) 400 kV Isolators and earth switches
c) 400 kV Voltage and current transformers
d) 360 kV Lightning Arrestor
e) 400 kV Gas Insulated Bus bars (GIB)
f) Local control panels and operating mechanism cabinets
g) Control & Relay Panels
h) SCADA system for monitoring and control of GIS equipment
i) LV panels as required
j) Earthing, Lightning, Illumination system and other miscellaneous items.
k) Pothead yard for transmission line connection
l) EOT carnes

The GIS layout is finalized with due consideration to the statutory safety requirement, ease of erection, maintenance, etc.

The clearances will be adequate for moving portable equipment for maintenance and maneuvering personnel for carrying out maintenance. Clearances from adjacent live parts will be maintained for safety.

10.2.10 *Control & Protection Equipment*

Generator / Motor control and protection

Units will be operated from central control room through UCB/Supervisory Control & Data Acquisition (SCADA) system in Auto / Manual mode.

Machines can also be operated by manually switching on each auxiliary during testing mode.
Synchronizing panel will be provided with facility of auto and manual synchronizing of the units. The UCB will also have the scheme for mechanical protection. All machine faults as well as the network faults, will be detected and alarms and/or tripping orders will be generated.

The unit protection will be achieved through numerical protection relays housed in Unit Protection Panel (UPP). Protections will be configured into two independent sets of protections (Group A & B) acting on two independent sets of trip coil fed from independent D.C. supplies, using separate set of instrument transformers, and segregated cables of CTs/VTs. UPP will be located in central control room.

Proper coordination between each protective relay settings will be maintained. Metering system will have necessary interface to the SCADA system. Tariff metering will conform to CEA regulations for tariff metering and will include main and check meters on outgoing lines as well as standby metering on HT side of Generator step up transformers.

10.2.11 *Auxiliary Electrical Services*

Common Unit Transformers (CUT):
Two Common Unit transformers (CUT) of 15/11.5kV rating will get power tapped from generator busduct of DFIM machines for supplying entire auxiliary power for powerhouse and SFC based starting power to the constant speed generator motors through 11kV Switchgears.

Unit Auxiliary Transformers (UAT) & Station Auxiliary Transformers:

There will be five Unit auxiliary transformers (UAT) of 11/0.433kV rating one per unit feeding the unit loads through unit auxiliary board. There will be two station auxiliary transformers (SAT) of 11/0.433kV rating feeding the station loads through station auxiliary board (SAB). UAT & SAT will be fed from 11 kV switchgears. The impedance of UAT/SAT will be selected on consideration of LV fault level.

One stand-by transformer of rating 11/0.433kV will be connected with all UAB & SAB boards through tie feeders, which will be taken care failure of any one of UAT or SAT.

The SAB will feed dewatering/ drainage system, HVAC loads, lighting, maintenance, crane, elevator, DC system, etc.

Emergency Diesel Generator Set

Two nos. of 1 MVA, 11 kV, sound proof DG set along with AMF panels are considered to supply the emergency loads through 11 kV switchgear. Alternator will have class F insulated winding with temperature limited to class B.

DC Auxiliary Services

For control, protection and emergency lighting of the powerhouse, two sets (i.e., 2x100%) of 220V DC Station battery with two sets of battery chargers (2x100% float cum boost) of adequate capacity, DC distribution Board will be provided. DC Batteries will be of lead acid Plante type.

10.2.12 *Cables*

All cables will be selected to carry the full load current under site conditions, with permissible voltage drop / dip. In addition, these cables will be rated for short circuit capacity wherever required. The following types of cables will be used:

(i) For 400kV power cables – 400kV grade, stranded aluminum / copper conductor, XLPE insulated, screening, water blocking layer, PVC sheathed, armored, FRLS PVC overall sheathed cables conforming to IEC-62067.

(ii) For 11kV power cables – 11kV (UE) grade, stranded aluminum conductor, XLPE insulated, PVC sheathed, armored, FRLS PVC overall sheathed cables conforming to IS-7098.

(iii) For low voltage power cables - 1100V grade, stranded aluminum conductor, XLPE insulated, color coded, PVC sheathed armored, overall FRLS PVC sheathed cables conforming to IS-7098.

(iv) Control and protection cables - 1100V grade, annealed high conductivity stranded copper conductor, PVC insulated, PVC inner sheathed, armored, and overall FRLS PVC sheathed.

(v) Signaling and supervisory cables - Annealed tinned copper conductor in stranded circular construction, PVC insulated, PVC inner sheathed, armored, and overall FRLS PVC sheathed, in twisted pairs, and screened.

(vi) Cables will be laid in ladder / perforated type galvanized steel cable trays or in trenches. In outdoor areas, cables will be laid in built-up trenches.

10.2.13 *Lighting*

The lighting system will be inclusive of indoor/outdoor lighting equipment, maintenance power supply networks, and power supply outlet circuits in GIS substation / switchyard and in powerhouse. Lighting system will provide normal and emergency lighting scheme for the indoor and the outdoor areas, luminaries with fluorescent, HPSV/MH mounted on wall/columns. Also the intake and tailrace will be provided with required lighting.

a. Normal 240V AC Lighting
b. The light fittings, fans & receptacles will be fed from 415V, 3 phase, 4 wire, lighting panel, which in turn will be fed from the 415V switchgear. The lighting system will cover the entire power house areas like TG hall, control room / switchgear room, battery room, maintenance bay, stair case, entrance, transformer area, GIS hall, DG house, power house periphery, pothead yard, roads etc.
c. D.C. Emergency Lighting
d. DC emergency lighting will be provided at strategic points in the power station, viz. near entrances, staircases, and control room. These will be fed from station 220V DC system and will be off when the normal AC power supply is available. These will be automatically switched on when the normal AC supply fails.

10.2.14 *Earthing & Lightning Protection*

Earthing and lightning protection system will be provided to ensure equipment safety, personnel safety and to facilitate designed operation of protective devices during earth fault conditions in the associated system. Buried earthing conductor will be MS flat of adequate cross section. The overall plant grounding system will include the powerhouse grounding grid, transformer yard grounding grid. Separate Switchyard grounding, tailrace tunnel grounding grids and access tunnel grounding grids. All the grounding grids will be interconnected to one another.

Lightning protection will be provided as per Indian Code of Practice. The system will consist of air termination rods, horizontal roof conductors, down comers, test link and earth pits. The earth pits for the lightning protection will be inter connected only underground.

10.2.15 *Power Evacuation*

Power from Pumped Storage project will be evacuated to / drawn from 400kV grid substation through 400kV single circuit line on multi circuit tower. For this purpose, 400kV transmission line feeders are provided in GIS substation to connect with grid for power evacuation. Interconnection of line is considered between Kurukutti PSP & Karrivalasa PSP along with N+1 line at Karrivalasa PSP i.e one stand-by transmission line is provided from Karrivalasa PSP substation to take care of power transfer during failure of the lines.

220/400kV Maradam substation is considered as a grid station, which is approximately 40 km away from project site for evacuation / drawal of power from proposed Kurukutti PSP & Karrivalasa PSP's. As the power requirement for the pumping mode of PSP will be drawn from the same 400kV grid station, the adequacy of the gird station capacity shall be verified. However, the selection of substation, transmission line networks, voltage and adequacy check shall be ascertained by APTRANSCO by carrying out the detailed grid studies before finalisation of project.
At grid station, 400kV bays with all the facilities shall be developed to accommodate the new lines from both PSP's.

10.2.16 *Power requirement for pumping*

The synchronous/DFIM machines will be operated as synchronous motors to pump water back from the lower reservoir to the upper reservoir. The power requirement for the pumping mode will be drawn through the same 400kV GIS substation and the 400kV transmission lines by back-feeding the generator transformers. The power required for pumping shall be made available at 400kV grid by client during the pumping interval.

10.2.17 *Bus Shunt Reactor*

Shunt reactor will be provided to limit over voltages during line energization / load rejection.

The shunt reactor will be of star connected winding, oil filled, rated either three nos. single phase 21 MVAR,400/√3 kV or one no. 3 phase 63 MVAR, 400 kV with necessary switching & control arrangements. The reactor will be complete with all accessories and sufficient mineral oil for first filling. The shunt reactor will be connected by Gas insulated Busduct (GIB) with 400kV GIS main bus.

The shunt reactor rating shown is indicative value. The selection of shunt reactor type, rating and adequacy check shall be ascertained by APTRANSCO by carrying out the detailed grid studies before finalisation of project.

10.2.18 *Communication*

Communication from PSP to grid station will be carried out using Fiber Optic media. Both ends of the transmission line will be provided with Fiber Optic Terminal Equipment. OPGW ground wire will be used which will serve dual purpose of ground wire and communication. Fiber optic communication is proposed to interconnect various site locations such as of power station, switchyard, and dam by establishing a fast Ethernet for voice, data and video communication between all the sites of the project and as required.

The fiber optic system will be suitable for voice and data communication, power circuit Tele-protection signaling, Supervisory Control and Data Acquisition (SCADA), Security Management System (SMS) and CCTV application.

Equipment required for load dispatch function shall be in line with APTRANSCO/POWER GRID specification and requirements.

Microprocessor based digital EPABX system is proposed at a control room located in power station and is planned for intercom purpose. EPABX system will cater to the voice communication requirement of the PSP covering various project areas such as power house along with all the associated floors and access galleries/areas to pothead yard and Upper Dam as required.

In addition, Public address system is proposed and will be located in the control room of powerhouse. The loud speakers, the head microphones, the call station connecting points and the other telephone connecting points shall be located at various points of power house, pothead yard & Dam.

Chapter - XI
Construction Programme & Plant Planning

11.1 General

The proposed Kurukutti PSP is a pumped storage project with an installed capacity of 1200 MW. Upper dam is located near Chemidipatipolam village and lower dam is located near Kurukutti village in Salur Taluka, Vizianagaram district of Andhra Pradesh state.

In the turbine mode, a vertical intake draws water from the upper reservoir and conveys to a headrace tunnel follower by pressure shaft, which further divides into five (5) branches near the powerhouse. The five pump-turbine units are located inside the shaft type powerhouse. From the draft tubes in the powerhouse, a tailrace tunnel conveys the water into the lower reservoir. In pumping mode, water is pumped from lower reservoir through a vertical intake and is let back into upper reservoir through the same water conductor system.

11.2 Completion Time and Available Working Season

Construction programme, selection of methodology and equipment has been planned with the aim of commissioning of the project in five years. Available working season in a year shall be of 12 months for all underground works, 9 months for surface works above river bed and works in the river bed.

11.3 Approach Road and Location of Project

Both upper and lower dams are accessible from Visakhapatnam and are situated about 155 km from Visakhapatnam city (via Vizianagaram & Salur towns) and about 25 km from Salur, which is the nearest town. The nearest international airport and sea port is at Visakhapatnam which is about 140 km from the project site. The nearest railway station is at Salur, which is situated at a distance of around 25 km from the project site.

Access to project site from Salur town/rail head is available upto proposed lower dam site near Nerellivalasa (Kurukutti) village, which is a major district road and metalled. Further village roads connecting Nerellivalasa to nearby villages existing near the proposed project sites are available and could be used for project after strengthening (i.e., metalled road). The length of road that required to be strengthened is found to be about 5 km. In addition to the above, 10 km of new approach roads are required to be constructed for providing access to upper dam/intake, surge shaft area, powerhouse site and reconstruction of existing road that will be submerged under the lower reservoir.

The mode of execution of the project is assumed to be an engineering, procurement and construction (EPC) manner. Hence, minimum activities are planned by the owner, limiting to functions such as construction of camps, roads, O & M and other essential infrastructural services required before the major construction agencies move in.

As a preliminary estimate, a construction period of 5 years (60 months) from the date of award of civil works package has been estimated for this project.

Approach roads, bridges and other related works are to be taken up in advance for earlier start of actual excavation of underground structures. Therefore, it is planned to get approach roads completed in the interim period between the project sanction by Government and award of work for civil works through own arrangements or item rate contracts. This will enable the construction agency under civil works package to take up the construction of individual project components with approach roads ready in hand before mobilization at site.

11.4 Construction Material

11.4.1 *Cement*

Salur railway station, which is at a distance of around 25 km from the project site, will be used as rail head. Cement required for construction of project will be supplied from Visakhapatnam and transported to Salur by means of existing railway line. Bagged cement shall be transported in trucks from Salur and stored in project stores at different sites.

11.4.2 *Steel*

Steel stockyards nearer to the project site shall be the main source of structural and reinforcement/ tor steel. Sizeable quantities of reinforcement steel and structural steel shall have to be stocked and replenished regularly. Steel plates for pressure shaft liner, if not available indigenously however, may have to be imported to suit the design specifications.

11.4.3 *Aggregate*

The material in the river bed may be suitable for aggregate, however, the same has to be got tested during DPR investigation stage. Excavated rock from headrace tunnel, surge shaft, pressure shaft, powerhouse and tailrace tunnel could be crushed and classified to various sizes of aggregate in batching and mixing plant at suitable locations.

11.4.4 *Stores, Lubrication & Work Shop*

The Petrol/diesel pumps, explosives magazine, workshops and other construction facilities shall be provided to facilitate execution of the project. The central stores for storage of cement, T&P articles, steel yard and main workshop shall also be provided. Site stores and field workshops will be established near respective sites. Petrol/diesel pump shall be established near the power house site.

11.4.5 *Dump Areas*

Excavation for tunnels, pressure shaft and powerhouse will involve large quantities of muck. The excavated rock will be utilized as aggregates for concrete to the extent possible. The rest needs to be disposed-off in a planned and environmental friendly manner. This is the most important aspect to be dealt with. It is proposed that at different locations dumping sites will be identified at suitable places. After the filling is done, rehabilitation of this site will be carried out to ensure that neither it flows in to the water stream nor it poses other environmental threat. Plantation, wherever possible, will also be done on these sites so that these get stabilised over a period of time and do not pose any environmental problem. The excavated muck shall be dumped in dumping areas identified. Dozers shall be deployed in dump areas for spreading and compaction of dumped material.

11.4.6 *Construction Schedule*

The estimated time for construction of civil work is about 45 months and the balance 15 months has been considered for testing and commissioning of 5 pump-turbine generating units. Method of execution of various components and selection of equipment have been done with the object that Commissioning of all units as a whole will be completed in 60 months duration. The preliminary year wise construction programme for execution of various civil and electro-mechanical works is furnished given in Exhibit - 17.

Chapter - XII
Infrastructure Facilities

12.1 General

The project envisages construction of two reservoirs, an upper intake, headrace tunnel, surge shaft, pressure shaft, shaft type powerhouse, tailrace tunnel and a lower intake. Owner will procure a few transport and inspection vehicles and few very essential machinery to look after functions such as design engineering, timely processing of construction drawings, work supervision, project monitoring, periodical review meetings, Quality assurance and Quality Control, overseeing works progress, quantity measurement and timely payment. Two project site offices i.e., one near Kurukutti village and the other at the powerhouse location would be required.

12.2 Access Roads

12.2.1 *Roads to Project Site*

Salur, which is the major town and nearest railhead for the project site is located at a distance of about 120 km from Visakhapatnam, which is the nearest major sea port and airport in the project region. There exists a major district road (metalled) connecting Salur town with Nerellivalasa (Kurukutti) village. It is suggested to use the Salur-Nerellivalasa road to access the proposed project site.

Access to project site from Salur town/rail head is available upto Nerellivalasa village, which is a major district road and metalled. Further village roads connecting Nerellivalasa to nearby villages existing near the proposed project sites are available and could be used for project after strengthening (i.e., metalled road). The length of road that required to be strengthened is found to be about 5 km. In addition to the above, 10 km of new approach roads are required to be constructed.

12.2.2 *Bridges and Culverts*

The road bridge and culverts along the existing road may need strengthening depending on the expected weight of equipment to be transported. This aspect needs to be reviewed further during DPR stage after detailed route surveys.

12.3 Rail Head

Railway station at Salur is located at a distance of about 25 km from project site.

12.4 Port Facilities

Visakhapatnam sea port, located at a distance of about 140 km from project site is the convenient Port and Harbour for all imported consignments.

12.5 Construction Power

Construction power is required for running the construction machinery, for lighting in all construction area, colony roads, water supply and dewatering in all work sites, ventilation arrangement inside powerhouse and underground works. It is proposed to arrange one no. 33kV temporary feeder from the nearest AP TRANSCO Substation up to the project site. Suitable rating of transformers and switchboards will be arranged to feed the various load centre & during construction phase. However, during the initial starting stage of the project two nos. of 50kVA emergency DG set will have to be arranged for providing power to site offices and construction activities.

12.6 Tele-communication Facilities Required During Construction and after Completion of Project

The proposed project site is relatively in a remote location with limited coverage of mobile network from national telecom providers (BSNL, Airtel). Hence, it is suggested to provide an independent communication system for the project during construction itself.

12.7 Project colonies, Buildings and Workshops

Project labour colony and site offices including workshops/fabrication yard could be planned near Kurukutti village located in the vicinity of the project area.

12.8 Drinking Water Facilities

Water available in both the reservoirs could be used for construction and for drinking after treatment.

12.9 Other Facilities

12.9.1 *Explosive Magazine*

This will be constructed at an extreme corner of acquired land free from all types of incumbency. It will be constructed and maintained by the main contractor and serve others also, as needed.

12.9.2 *Quality Control Laboratory*

This will be constructed in the common facilities area near Kurukutti village or any of the dam sites.

12.10 Land Requirement

The total land required for the project components and related works has been estimated to be about 638 Acres, which includes 628 Acres of land that needs to be acquired and 10 Acres of land which needs to be taken on lease basis. In addition to the above, the extent of land involved for Right of Way (RoW) for underground works & transmission line has been estimated to be about 460 Acres. The overall land requirement for the project & land area apportioned to Kurukutti PSP is furnished in Table - 12.1.

Table - 12.1: Land Requirement

Sl. No.	Description / Project Component	Area (Acres)	
		Overall	Apportioned to Kurukutti PSP
I	**Land to be Acquired**		
1	Upper dam/reservoir (incl. upper intake)	144	144
2	Powerhouse complex	15	15
3	Lower dam/reservoir (including lower intake)	405	203
4	Approach road	3	3
5	Offices & Colony	5	5
6	Dumping Area	50	50
7	Bay Extension	6	3
	Sub-Total	**628**	**423**
II	**Land (Lease)**		
1	Labour Colony	10	10
	Sub-Total	**10**	**10**
	Grand Total	**638**	**433**

Chapter - XIII
Environmental and Ecological Aspects

13.1 Description of the Project

The project envisages utilization of head available between proposed upper and lower dams located in Boduru Gedda sub-basin of Suvarnamukhi river. Both upper and lower dams are located in Salur Taluka, Vizianagaram district. During peak hours, water stored in upper reservoir will be used to generate 1200 MW peak power and stored in lower reservoir by utilizing a gross head of about 589 m. When power demand falls, water stored in lower reservoir will be pumped back into the upper reservoir. Ecology and environmental aspects as available from public domain are briefly covered in the following paragraphs. However a detailed EIA studies will be carried out during the DPR stage.

13.2 Description of Environment

13.2.1 *Flora*

The nature and type of vegetation occurring in the area depends upon a combination of various factors including prevailing climatic conditions, altitude, topography, slope, biotic factors, etc. The Eastern Ghats is home to various species of plants and animals. Common tree species that grow within the range include Meliosma microcarpa, Cinnamomum zeylanicum, and Elaeocarpus serratus. Vegetation around the project region is largely tropical dry deciduous forests, moist deciduous forests and scrub deciduous forests.

13.2.2 Fauna

The Eastern Ghats is also inhabited by various reptiles, mammals, birds, and amphibians. Examples of mammals that live within the range include the monkey, Indian elephant, Asian palm civet, small Indian civet, and Indian crested porcupine. Bird species known to live in the Eastern Ghats include the spot-billed pelican, great Indian bustard, and pied crested cuckoo. Examples of amphibians include the cricket frog, Gunther’s toad, and golden-backed frog. Common reptile species include the Indian flap shell turtle, mugger crocodile, and Indian chameleon.

13.3 Environment Impact Assessment and Evaluation

13.3.1 *Impact Identification*

Based on preliminary studies, both direct and indirect environmental impacts on various environmental attributes due to proposed Kurukutti pumped storage project on the surrounding environment, during construction & operational phase has been identified and described in the following sections.

13.3.2 *Impact Identification During Construction Phase*

The impacts due to construction of Kurukutti PSP, powerhouse installation commence from the exploration activities, construction of pressure shaft, tunnels, powerhouse, approach roads, etc., may continue up to generation of hydel power, with the nature and extent of impacts varying throughout the stage of project development. Activities like site preparation, approach roads, excavation, drilling, blasting, foundations, tunnelling, deployment of machinery, erection, transportation, dumping is taken up during construction phase. The likely impacts on the environment due to these activities are listed in table. Tunnelling and foundation works will involve land excavation, filling and concrete works effecting environment by noise and dust pollution. Structural, deployment of machinery, approach roads construction and erection work will also result in dust, noise pollution and vehicular traffic. Material handling and transportation may significantly increase noise pollution. The labour for various activities during the construction phase shall be engaged from the surrounding villages. Some essential services are also required to be provided. This will have an impact on drinking water supply and sanitary facilities. Economy of the nearby area will be improved due to increased job opportunities with corresponding increase in income. Other associated business activities like transport, hotels, consumer goods etc., will also be benefited. The major environmental parameters likely to be affected during construction phase are noise, dust pollution and sanitation. Water spraying during high dust will minimise the dust level to some extent. A proper temporary housing with water supply and sanitation for workers should be planned. The effect due to construction phase is however, of temporary in nature and has no permanent effect on environment.

Sl. No.	Construction Phase	Activity	Potential Environmental Impact
1.	Site work / providing other Facilities.	Clearing and grading	Negligible
		Temporary facilities, such as, sheds approach roads, Sanitary facilities.	Dust emission and change in traffic intensity.
		Earth work comprising of Excavation and trenches.	Soil erosion, run off, increase in traffic, Dust emission
		Foundation work, Construction of Tunnels and portals.	Dust, visual and noise pollution
		Construction of permanent structures like roads, colony etc	Dust and noise pollution
		Mechanical erection and utility systems	Dust, noise and visual impact.
2.	Construction of approach roads, tunnelling works and construction of powerhouse	Excavation	Dust, soil erosion, wastewater generation & noise
		Drilling and blasting	Dust, noise and health hazards
		Dumping	Dust, noise and visual
		Transportation	Dust, noise and visual

13.3.3 *Impact Identification During Operational Phase*

There would be no environmental and ecological changes during the operational phase. Since hydro power is green power, environment impact on the surrounding environment is not during operational phase.

13.3.4 *Prediction of Impacts*

The impact during construction of Kurukutti PSP on environment (air, water, noise, land etc. are predicted in this section. The construction activity may cause some adverse impacts on the surrounding environment unless proper environmental management plan is adopted. No impact during operation phase is predicted.

a) Impact on Air Environment

Considerable amount of air pollution will be caused during different stages of construction of reservoirs, tunnels, roads and other operations such as excavation, drilling, blasting, loading and transportation of material. Suspended Particulate Matter (SPM) is the main pollutant during construction. Most of the dust arises from drilling, blasting, excavation, crushing and transportation operations. Large quantities of dust become wind borne and are carried away from overburden dumps. The fugitive dust released during the construction activities may cause immediate effect on the construction workers who are directly exposed to the fugitive dust. Vegetation will also be adversely affected as deposition of dust on the leaves will choke the photosynthesis activity, which, in turn, will have adverse effect on the health of the plants.

b) Impact on Noise Environment

The noise will be generated at the time of construction of powerhouse, tunnelling, drilling machines, dumpers, etc. Continuous exposure of workers to high level of noise may result in annoyance, fatigue, and may cause temporary shift of threshold limit of hearing and even permanent loss of hearing. During operational phase, noise level will be increased due to trouncing machinery and vehicular movement in the area. However, these impacts are only localized.

c) Impact on Water Environment

During the construction of tunnel and powerhouse, surface water (river water) may get polluted due to the generation of large quantities of suspended particulate matter at the time of transportation of muck and waste water (sewage) coming from temporary arrangements like offices, labour camp sheds, etc.,

d) Impacts on Flora and Fauna

During DPR stage, detailed Environmental studies are recommended to be conducted to ascertain the ownership status of the lands, i.e. whether the land belongs to forest department or is it a non-forest government land. Even barren land, could be categorized as forest land, if it is under the jurisdiction of forest department. In such a scenario, compensatory afforestation as per the norms of Forest Conservation Act (1980) will have to be done in lieu of entire forest land as per ownership, irrespective of its vegetal status to be acquired for the project. The ownership category of land required for various project appurtenances can be ascertained, once project layout is finalized as a part of DPR preparation. Based on type of land being acquired for the project, suitable compensatory measures can be suggested as a part of EIA study.

13.4 R & R Aspects

Based on the preliminary layout formulated for proposed Kurukutti PSP, the project prima-facie involves submergence of agricultural lands in Chemidipatipolam village under the upper reservoir and Kurukutti village under the lower reservoir. Further, the project also involves submergence of existing habitations at Rampadu, Tadivalasa, Nerellivalasa and Kotha colony. The total area of land under submergence of upper and lower reservoirs is about 143 Acres and 394 Acres respectively. In addition to the above land under submergence, additional land is required for construction of civil structures and allocation of quarry areas, which requires acquisition of government/private lands.

A detailed socio-economic survey needs to be conducted during EIA study , based on which suitable Resettlement & Rehabilitation Plan can be formulated.

13.5 Environmental Management Plan (Mitigation Measures)

Environmental Management Plan (EMP) aims at the preservation of ecological system by considering certain mitigating measures at the proposed site. The mitigation measures are used to minimize or prevent adverse impacts on environment due to the proposed development activity. Some of the major criteria governing the environmental measures will be adopted, and the same is described in the following paragraphs.

a) Environmental Management

The EMP is required to ensure sustainable development in the area of the proposed project site. It is expected that the study area shall not be affected much with the proposed activity. The majority of the environmental impact pertains to the construction phase. It is planned to take corrective measures to ensure that these effects are kept to bare minimum. The EMP will therefore, be initiated during planning stage itself.

b) Environmental Management at Construction Stage

Site Preparation

Dust emission (fugitive) and solid waste will be generated during initial site preparation activity and there will be slight increase in the noise levels around the site. The environmental impacts during the clearing for site preparation will be temporary, localised and negligible. Water sprays at appropriate location will be provided for dust suppression, hence reducing the impacts. Solid waste will be disposed-off along with the muck at the designated sites.

Air Environment

As discussed earlier, construction of Kurukutti PSP activities will generate large quantities of dust during drilling, blasting, loading and transportation operations. The following measures are required be taken to mitigate the fugitive dust from different operations.

- To avoid the dust generation from the drilling operations, wet drilling methods will be adopted.
- Ceasing dust - generating activities during high winds
- Covering of vehicles carrying solid waste (muck).
- Watering of haul roads and other roads at regular intervals
- Plantation near muck disposal places and dumping yards.

Noise Environment

The major noise generating sources from the proposed activity are working machinery, blasting and movement of vehicles. The following control measures are to be undertaken to bring down the noise levels.

- Traffic (vehicular movement) to be managed to produce a smooth flow instead of a noisier stop -and start flow.
- Ensuring timely preventive maintenance of the equipment involved. Since a well maintained equipment is generally quieter than poorly maintained equipment.
- Ensuring usage of personal protective devices i.e., earmuffs and earplugs by workers, working in high noise activity centres.
- Plantation in the vicinity of the construction area will further reduce the noise levels.

Water Environment

During construction phase the wastewater (sewage) coming from temporary Arrangements like offices, labour camp sheds, canteens etc., and impact due to soil erosion during monsoon period may cause surface water pollution. Some of the control measures adopted for controlling water pollution are as follows:

- Establishing septic tanks followed by soak pits to treat the domestic waste water generated from the offices, canteens, labour camp sheds.

- Construction of Check dams /rock fills dams, wherever necessary to reduce siltation and suspended solids.

Green Belt Development (Compensatory Afforestation)

Afforestation is proposed to be done in open areas with moderate slope. This has to be supplemented with engineering/vegetative works like gully plugging and check dams etc wherever required. There is very limited scope of plantation. Where ever plantation is undertaken it should be closed to grazing, lopping etc. For proper protection, it is necessary that the area is fenced and the fence is maintained properly. Plants need to be protected till they attain a height, which is above grazing level.

Disposal of Muck

Excavation in tunnels, pressure shaft and powerhouse will involve large quantities of muck. The excavated rock will be utilized as aggregates for concrete to the extent possible. The rest needs to be disposed-off in a planned manner. This is the most important aspect to be dealt with. It is proposed that at different locations dumping sites will be identified at suitable places. Retaining walls will be constructed. After the filling is done, rehabilitation of this site will be done to ensure that neither it flows in to the water stream nor it poses other environmental threat. Plantation, wherever possible, will also be done on these sites so that these get stabilized over a period of time and do not pose any environmental problem.

Chapter - XIV
Cost Estimates and Economic Evaluation

14.1 General

Cost of project has been calculated as per "Guidelines for Preparation of Estimates for the River Valley Projects" issued by CWC and "Recommendations of Committee on Cost Control on River Valley Projects". The cost of civil and hydro-mechanical works is based on preliminary quantity estimation for major items and Schedule of Rates issued by Government of Andhra Pradesh for the year 2020-21. The unit rates for major items are furnished in Annexure - 14.1.

The cost of Electro Mechanical equipment is based on budgetary quotations received from reputed PTG vendors for similar PSP projects in India.

14.2 Basis of Cost

The basis of project cost under various heads as per the Guidelines for Preparation of Estimates for the River Valley Projects considered for the project is described herewith.

A - Direct Cost

a) *I - Works*

Under this head, provision has been made for following works of project, as detailed hereunder:

A - Preliminary

The provision under this head covers the works relating to various investigations, Surveys, Model tests, ecological studies etc. This should be based on the actual cost likely to be incurred and should not exceed 2% of the total cost of I-Works.

B - Land

The provisions under this head covers Acquisition of land, rehabilitation & resettlement including compensation for property, Interest charges, Solatium charges, demarcation & measurement charges etc. For the present study, cost of land has been assumed as Rs 5.0 Lakhs/Acre towards acquisition and Rs 50,000/annum/year towards land obtained on lease.

C - Works

This covers the cost of civil works of river diversion arrangement, RCC dam, spillway and their appurtenant works including provisions towards Hydro Mechanical Works i.e. Gates, Hoisting Equipments, Trash Rack, Stop logs etc.

J - Power Plant Civil Works

This covers the cost of civil works of intakes, HRT, surge shaft, pressure shaft, powerhouse, tailrace etc., and their associated works including provisions towards Hydro Mechanical Works.

K - Buildings

Under this head, provision has been made for the expenditure to be incurred both on permanent and temporary residential and non-residential buildings. The non-residential buildings include office buildings, laboratory, workshop, store, sheds, guest houses and field hostels.

M - Plantation

Under this head provision has been made for plantation, for beautification in the downstream of Dam and appurtenances, Powerhouse and other structures, colony, and along roads.

O - Miscellaneous

Under this head provision has been made to cover the capital cost, repair & maintenance of electrification, Water supply, Sewage disposal and drainage works, Recreation, Medical, Fire-fighting equipment, Inspection vehicles, School bus, Pay van, Visit of dignitaries, Welfare works etc. For projects with cost of I - Works greater than Rs 2000 Crores, Miscellaneous cost is estimated @1.5% of the cost of I-Works greater than Rs.2000 crores limited to Rs. 40 crores).

P – Maintenance During Construction

The provisions under this head covers the cost of maintenance of all works during the construction period. A provision of 1% of the total cost under the heads of C-Works, J-Power House Civil Works and K-Buildings is made.

Q - Special T&P

The provisions under this head covers the Drilling & Grouting equipments, Transport, Compaction, Electrical equipments, Construction Plant & Earth Moving equipments and other miscellaneous equipments. Since the project is proposed to be developed by EPC mode of contract, Contractor shall arrange for the necessary equipment. A token provision of Rs. 1-2 crores under this head may be adequate to provide for essential equipment not covered under contract package.

R - Communications

Provision has been made under this head to cover the cost of project roads, approach roads, quarry roads, temporary roads in the work area, bridges and culverts, strengthening of existing roads, bridges, etc.

S - Power Plant & Electrical System

Provision under this head has been made to cover power plant equipment and electrical system to be installed at the power houses such as generating units and associated auxiliary equipments and Switch Yard Equipment etc

X - Environment& Ecology

Provision under this head has been made to cover the expenditure on works relating to environmental ecological studies like EIA & EMP studies, compensatory afforestation, CAT plan etc. For the present study, cost towards the above works has been taken @ 1.5% of cost of I-Works.

Y-Losses on Stock

A provision of 0.25% of the total cost of C-Works, J-Power Plant Civil Works and K-Buildings has been made under this head.

Establishment

Provision under this head has been made as sum of the following:

- Civil works - Rs. 60.00 Crores plus 4.00% of cost exceeding Rs. 750 Crores and
- E&M works - Rs. 67.5 Crores plus 2.25% of cost exceeding Rs 1500 Crores

Tools & Plants:

The provisions under this head covers survey instruments, camp equipments, office equipments and other small tools. A token provision of Rs. 1-2 crores under this head may be adequate.

Indirect Charges

Provision for

i) Capitalization of abatement of cost of land revenue - A lumpsum amount of Rs 1 Crores has been made.

ii) Audit & Accounts charges @ 0.25% of I-Work more than Rs. 1000 crores subject to minimum of Rs. 5 crores

Financing Charges

A provision of 1% of I-Works has been made under this head towards the loan processing charges levied by financial institutions.

14.3 Allocation of Cost

As explained in Chapter - IX, it is proposed to provide for the net storage required for lower reservoir of both Kurukutti and Karrivalasa PSP's at the same location, in order to optimize the overall project cost and land requirement for the above two projects. Accordingly, the capital cost under various head has been apportioned as given below:

a) Cost of lower dam along with land acquisition costs has been apportioned between Kurukutti and Karrivalasa PSP's in 50%:50% proportion (as net storage requirement for both PSP's is same).
b) Cost of Preliminary works, Buildings and Communication works chargeable to Kurukutti PSP has been reduced by about 20% to account for rebate towards common lower reservoir.
c) Cost of transmission line has been apportioned between Kurukutti and Karrivalasa PSP's in the ratio of respective project capacities (1200 MW : 1000 MW).

Cost provisions for other items has been made as per respective provisions recommended as per the prevailing norms.

14.4 Abstract of Project Cost

The abstract of overall project cost and corresponding cost apportioned to Kurukutti PSP is summarized in Table - 14.1.

Table - 14.1: Abstract of Project Cost

Sl. No.	Item Description	Capital Cost (Rs. in Crores)	
		Overall Cost	Cost Chargeable to Kurukutti PSP
I	**Works**		
A	Preliminary	64	52
B	Land	32	22

Sl. No.	Item Description	Capital Cost (Rs. in Crores)	
		Overall Cost	Cost Chargeable to Kurukutti PSP
	Power Plant (Refer Annexure - 14.2)		
C	Civil Works	532	405
J	Power Plant Appurtenances	874	874
K	Building	60	48
M	Plantation	2	2
O	Miscellaneous	40	40
P	Maintenance	15	14
Q	Special T&P	2	2
R	Communication	12	10
S	Power plant and electrical system (Electro-mechanical equipment)	2400	2400
	Power Evacuation	133	73
X	Environment and Ecology	64	60
	Sub Total (I - Works)	**4230**	**4002**
II	Establishment	175	170
III	Ordinary T&P	2	2
IV	Losses on stock	4	4
V	Receipt and Recoveries	-1	-1
VI	Capitalised abatement on Land revenue	1	1
VII	Audits and accounts	11	10
VIII	Financing charges	43	40
	Basic Project Cost	**4465**	**4228**
IX	Interest during construction (IDC)	570	538
	Grand Total (I to IX)	**5035**	**4766**

14.5 Economic Evaluation

14.5.1 *Input Parameters*

Kurukutti PSP is a Pumped Storage Scheme (1200 MW) envisaging peak annual energy generation of 2527 Mu. The estimated project cost is Rs. 4766 Crores including IDC & FC at 2020-21 price level.

The Conversion Cost (which excludes Cost of Pumping energy) has been calculated and financial analysis has been carried out for Return equity at “on pre-tax basis” i.e., 22.05 % for a period of 40 years, which consists of 16.5% post-tax Return on Equity & applicable Corporate Income Tax.

The parameters considered in the economic evaluation of the project have been listed below and the tariff calculations are carried out as per CERC guidelines.

Table - 14.2: Input Parameters for Economic Evaluation

Sl. No.	Parameter	Unit	Value	Remarks
	BASIC PROJECT COST (including FC)		4228.00	
	IDC		538.00	
1	TOTAL COST INCLUDING IDC & FC	Rs. in Crores	4766.00	-
	POWER COMPONENT (Total cost including IDC & FC -		4766.00	
2	DEBT (70%)		3336.20	
3	EQUITY (30%)		1429.80	
4	DEBT : EQUITY RATIO	70%	30%	As per CERC guidelines
5	RATE OF O & M CHARGES	%	3.50%	As per CERC guidelines
6	ANNUAL INCREMENT IN O&M CHARGES	%	4.77%	As per CERC guidelines
7	SPARES (15% of O&M CHARGES)	%	15.00%	As per CERC guidelines
8	INTEREST ON WORKING CAPITAL	%	10.50%	As per NREDCAP
9	RATE RETURN ON EQUITY	22.05%	22.05%	As per CERC guidelines (for Storage HEP's/PSP projects)
10	RATE OF DEPRECIATION	%	5.28%	As per CERC guidelines
11	DISCOUNTING RATE	%	10.45%	Calculated
12	INPUT ENERGY	Mu	3308	Estimated
13	ANNUAL ENERGY GENERATION	Mu	2527	Estimated
14	Aux. Consumption	%	1.20%	As per CERC guidelines
15	Weighted Average Rate of Interest	%	**10.50%**	As per NREDCAP
16	Plant Useful Life	Years	40	As per CERC guidelines

14.5.2 *Phasing of Expenditure*

The Project is proposed to be completed in 5 years and the phasing of expenditure is given in Table - 14.3. The phasing has been worked out based on the Proposed Construction Programme for implementation of Civil and Electro-mechanical works which is based on past experience in similar Projects.

Table - 14.3: Phasing of Expenditure

Half yearly period%	Expenditure	
	%	Amount (Rs. Crores)
6	5%	211.4
12	5%	211.4

Half yearly period%	Expenditure	
	%	Amount (Rs. Crores)
18	10%	422.8
24	10%	422.8
30	15%	634.2
36	15%	634.2
42	15%	634.2
48	15%	634.2
54	5%	211.4
60	5%	211.4
Total	100%	**4228**

14.5.3 *Interest During Construction*

The finance for the Project is planned to be raised through upfront 30% equity and the balance 70% would be met by obtaining loan from financial institutions with an expected interest rate of 10.5%. The interest during construction and financing charges have been worked out considering the phasing of expenditure as in Table - 14.3 and furnished in Table - 14.4.

Table - 14.4: Interest during Construction (Rs in Crores)

Distribution	*Period (Months)*	*Present Cost*	*Equity*	*Loan*	*Estimated IDC*
5%	6	211.4	211.4	0.0	
5%	12	211.4	211.4	0.0	
10%	18	422.8	422.8	0.0	
10%	24	422.8	422.8	0.0	
15%	30	634.2	161.6	472.6	12.0
15%	36	634.2	0.0	634.2	41.0
15%	42	634.2	0.0	634.2	76.0
15%	48	634.2	0.0	634.2	112.0
5%	54	211.4	0.0	211.4	140.0
5%	60	211.4	0.0	211.4	157.0
	Total	**4228**	**1430**	**2798**	**538**

14.5.4 *Levelized Cost of Generation*

The levelized cost of generation for the proposed Kurukutti PSP has been estimated considering the cost of pumping as Rs 3.0/kWh as per the latest CERC guidelines applicable for hydroelectric projects. Accordingly, the levelized cost of generation has been estimated to be Rs 7.85/kWhr. The details of calculations are furnished in Annexure - 14.3.

Further, levelized cost of generation is found to reduce drastically with reduction in cost of pumping, rate of interest and return on equity. For example, the levelized cost of generation has been estimated to be Rs 5.57/kWhr considering a) Cost of pumping @ Rs 2.00/kWhr, b) Rate of interest @ 6% and c) Return on Equity @ 10%.

14.5.5 *Sensitivity Analysis*

In order to evaluate project viability against different parameters and to facilitate project developers in identifying the best suitable combination of financial parameters, a sensitivity analysis has been carried out considering varying cost of pumping, rate of interest and post-tax return on equity and the resulting levelized cost of generation considering a plant life of 40 years is furnished in Table - 14.5.

Table - 14.5: Sensitivity Analysis

Sl. No.	Cost of pumping (Rs/kWh)	Post-Tax RoE	Levelized Tariff (Rs / kWh)			
			Rate of Interest @4%	Rate of Interest @6%	Rate of Interest @8%	Rate of Interest @10.5%
1	0.00	8%	2.64	2.75	2.89	3.10
		10%	2.78	2.90	3.05	3.27
		12%	2.91	3.04	3.20	3.43
		16.5%	3.21	3.37	3.55	3.81
2	2.00	8%	5.31	5.43	5.58	5.80
		10%	5.44	5.57	5.73	5.96
		12%	5.58	5.72	5.89	6.13
		16.5%	5.88	6.05	6.24	6.50
3	2.50	8%	5.98	6.10	6.25	6.47
		10%	6.11	6.24	6.40	6.64
		12%	6.24	6.39	6.56	6.80
		16.5%	6.55	6.72	6.91	7.18
4	3.00	8%	6.64	6.77	6.92	7.14
		10%	6.78	6.91	7.07	7.31
		12%	6.91	7.06	7.23	7.48
		16.5%	7.22	7.39	7.58	7.85

As seen from the above table, the levelized cost of generation is highly sensitive to the Cost of Pumping followed by Rate of Interest and Post-Tax Return on Equity.

Annexure - 14.1

Unit Rates of Major Civil Items of Works

Sl. No.	Description of Item	Unit	Rate (Rs)
1	Surface/Open Excavation:		
a	Open Excavation in all type of soils/overburden	M^3	195
b	Excavation in rock	M^3	320
2	Underground Excavation:		
a	Tunnel Excavation	M^3	2100
b	Shaft Excavation	M^3	2840
c	Overbreak	M^3	2100
3	Concreting Works:		
i	Dam Works:		
a	M15 A80	M^3	3460
b	M20 A80	M^3	3920
c	M25 A40	M^3	4970
d	M50 A40	M^3	8698
ii	Other Works:		
a	M15 A80	M^3	3745
b	M15 A20	M^3	5440
c	M25 A20	M^3	6115
4	Reinforcement steel in concrete works	MT	77200
5	Rock Anchors 25 mm dia	RM	1140
6	Rock Bolts 25 mm dia	RM	1140
7	Shotcreting with wiremesh	M^2	1480
8	Steel Ribs	MT	97305
9	Precast Lagging	M^3	7890
10	Drilling for consolidation & curtain grouting	RM	455
11	Drilling for contact grouting	RM	455
12	Drilling of 45 mm for drainage holes	RM	393
13	PVC pipe	RM	250
14	Cement for Grouting	Bags	585
15	Providing and constructing contracting joints by placing PVC water stop between blocks	RM	2281
16	RR Stone Masonry in CM 1:5	M^3	3128
17	Steel Liner for Pressure Shaft	MT	125000

Annexure - 14.2

Costing of Major Civil Works

ABSTRACT OF COST OF C-WORKS (Rs in Lakhs)				
Sl. No.	**Description**	**Civil Works**	**Hydro-Mechanical Works**	**Total**
C1	River Diversion (Upper & Lower Dams)	570	0	570
C2A	Dam (Upper Dam)	27400	0	27400
C2B	Dam (Lower Main Dam)	24790	430	25220
			Total	**53190**

ABSTRACT OF COST OF J-POWER PLANT WORKS (Rs in Lakhs)				
Sl. No.	**Description**	**Civil Works**	**Hydro-Mechanical Works**	**Total**
J1A	Power Intake - Upper	220	440	660
J1B	Power Intake - Lower	220	440	660
J2	Head Race Tunnel	4910	0	4910
J3	Surge Shaft	1250	100	1350
J4	Pressure Shaft	11270	46820	58090
J5	Power House Complex	18180	200	18380
J6	TRT	3260	0	3260
			Total	**87310**

Annexure - 14.3

Financial Analysis

ANNUAL GENERATION Av.Yr.(GWh)	2527.00	TOTAL COST OF PROJECT **INCLUDING IDC** (Rs.in Cr.)	4766.00	INTEREST RATE ON WORKING CAPITAL	10.50%
AUXILIARY CONSUMPTION (1.20%)	30.32	COST OF POWER COMPONENT INCLUDING IDC (Rs.in Cr.)	4766.00	RATE OF O&M CHARGES	3.50%
BALANCE AVILABLE AT BUS BAR	2496.68	DEBT (Rs.in Cr.)	3336.20	ANNUAL INCREMENT OF O&M CHARGES	4.77%
		EQUITY (Rs.in Cr.)	1429.80	SPARES CHARGES (in %age of O&M CHARGES)	15.00%
ENERGY AVIALABLE	2496.68	DEBT : EQUITY	70 30		
		WEIGHTED AVERAGE RATE OF INTEREST	10.50%	RATE OF DEPRECIATION	5.28%
ENERGY AVAILABLE FOR SALE	2496.68	LOAN REPAYMENT PERIOD	Match with Depreciation	RATE OF RETURN ON EQUITY(up to 18 years)	22.050%
Annual Pumping Energy (GWh)	3308.00			RATE OF RETURN ON EQUITY(After 18 years)	22.050%
Pumping Cost	3.00			DISCOUNTING FACTOR	10.45%

Sl No	OUTST-ANDING LOAN	INTEREST ON LOAN	DEPRE-CIATION	REPAYMENT OF LOAN (HALF YEARLY BASIS)	RETURN ON EQUITY	O&M CHARGES	O&M CHARGES FOR 1 MONTH	2 (Two) MONTHS BILLING	SPARES	WORKING CAPITAL	INTEREST ON WORKING CAPITAL	PUMPING COST	TOTAL CHARGES	SALEABLE ENERGY	TARIFF (Paise/unit)	DIS-COUNTING FACTOR	DIS-COUNTED TARIFF (Paise/unit)
1	2	3	4	5	6	7	8	9	10	11 =(8+9+10)	12	13	14	15	16	17	18
1	3326.20	336.04	251.64	251.64	315.27	147.98	12.33	347.24	22.20	381.77	40.09	992.40	2083.42	2496.68	834.48	1.00	834.48
2	3074.56	309.62	251.64	251.64	315.27	155.04	12.92	343.98	23.26	380.16	39.92	992.40	2063.89	2496.68	826.65	0.91	748.44
3	2822.91	283.19	251.64	251.64	315.27	162.43	13.54	340.78	24.37	378.69	39.76	992.40	2044.71	2496.68	818.97	0.82	671.33
4	2571.27	256.77	251.64	251.64	315.27	170.18	14.18	337.65	25.53	377.36	39.62	992.40	2025.89	2496.68	811.44	0.74	602.22
5	2319.62	230.35	251.64	251.64	315.27	178.30	14.86	334.58	26.74	376.18	39.50	992.40	2007.46	2496.68	804.05	0.67	540.28
6	2067.98	203.93	251.64	251.64	315.27	186.80	15.57	331.57	28.02	375.16	39.39	992.40	1989.44	2496.68	796.83	0.61	484.77
7	1816.33	177.50	251.64	251.64	315.27	195.72	16.31	328.64	29.36	374.31	39.30	992.40	1971.84	2496.68	789.78	0.55	435.03
8	1564.69	151.08	251.64	251.64	315.27	205.05	17.09	325.78	30.76	373.62	39.23	992.40	1954.68	2496.68	782.91	0.50	390.44
9	1313.04	124.66	251.64	251.64	315.27	214.83	17.90	323.00	32.22	373.12	39.18	992.40	1937.98	2496.68	776.23	0.45	350.48
10	1061.40	98.24	251.64	251.64	315.27	225.08	18.76	320.30	33.76	372.81	39.15	992.40	1921.78	2496.68	769.73	0.41	314.67
11	809.75	71.81	251.64	251.64	315.27	235.82	19.65	317.68	35.37	372.70	39.13	992.40	1906.08	2496.68	763.45	0.37	282.57
12	558.11	45.39	251.64	251.64	315.27	247.06	20.59	315.15	37.06	372.80	39.14	992.40	1890.91	2496.68	757.37	0.34	253.80
13	306.46	29.50	251.64	51.08	315.27	258.85	21.57	314.50	38.83	374.90	39.36	992.40	1887.03	2496.68	755.82	0.30	229.31
14	255.39	24.13	251.64	51.08	315.27	271.20	22.60	315.74	40.68	379.02	39.80	992.40	1894.44	2496.68	758.79	0.27	208.43
15	204.31	18.77	251.64	51.08	315.27	284.13	23.68	317.08	42.62	383.38	40.25	992.40	1902.47	2496.68	762.00	0.25	189.51
16	153.23	13.41	251.64	51.08	315.27	297.69	24.81	318.52	44.65	387.98	40.74	992.40	1911.15	2496.68	765.48	0.23	172.36
17	102.15	8.04	251.64	51.08	315.27	311.88	25.99	320.08	46.78	392.86	41.25	992.40	1920.49	2496.68	769.22	0.20	156.82
18	51.08	2.68	11.44	51.08	315.27	326.76	27.23	281.01	49.01	357.26	37.51	992.40	1686.06	2496.68	675.32	0.18	124.65
19	0.00	0.00	0.00	0.00	315.27	342.35	28.53	281.32	51.35	361.21	37.93	992.40	1687.95	2496.68	676.08	0.17	112.98
20			0.00		315.27	358.68	29.89	284.16	53.80	367.85	38.62	992.40	1704.97	2496.68	682.90	0.15	103.33
21			0.00		315.27	375.79	31.32	287.14	56.37	374.82	39.36	992.40	1722.81	2496.68	690.04	0.14	94.53
22			0.00		315.27	393.71	32.81	290.25	59.06	382.12	40.12	992.40	1741.51	2496.68	697.53	0.12	86.51
23			0.00		315.27	412.49	34.37	293.51	61.87	389.76	40.93	992.40	1761.09	2496.68	705.37	0.11	79.21
24			0.00		315.27	432.17	36.01	296.93	64.83	397.77	41.77	992.40	1781.60	2496.68	713.59	0.10	72.55
25			0.00		315.27	452.78	37.73	300.52	67.92	406.17	42.65	992.40	1803.10	2496.68	722.20	0.09	66.48
26			0.00		315.27	474.38	39.53	304.27	71.16	414.96	43.57	992.40	1825.62	2496.68	731.22	0.08	60.94
27			0.00		315.27	497.01	41.42	308.20	74.55	424.17	44.54	992.40	1849.22	2496.68	740.67	0.08	55.89
28			0.00		315.27	520.72	43.39	312.32	78.11	433.82	45.55	992.40	1873.94	2496.68	750.57	0.07	51.28
29			0.00		315.27	545.55	45.46	316.64	81.83	443.94	46.61	992.40	1899.84	2496.68	760.95	0.06	47.07
30			0.00		315.27	571.58	47.63	321.16	85.74	454.53	47.73	992.40	1926.97	2496.68	771.82	0.06	43.22
31			0.00		315.27	598.84	49.90	325.90	89.83	465.63	48.89	992.40	1955.40	2496.68	783.20	0.05	39.71
32			0.00		315.27	627.41	52.28	330.86	94.11	477.26	50.11	992.40	1985.19	2496.68	795.13	0.05	36.50
33			0.00		315.27	657.33	54.78	336.07	98.60	489.44	51.39	992.40	2016.39	2496.68	807.63	0.04	33.57
34			0.00		315.27	688.69	57.39	341.51	103.30	502.21	52.73	992.40	2049.09	2496.68	820.73	0.04	30.88
35			0.00		315.27	721.54	60.13	347.22	108.23	515.58	54.14	992.40	2083.34	2496.68	834.45	0.03	28.43
36			0.00		315.27	755.96	63.00	353.21	113.39	529.60	55.61	992.40	2119.23	2496.68	848.82	0.03	26.18
37			0.00		315.27	792.01	66.00	359.47	118.80	544.28	57.15	992.40	2156.83	2496.68	863.88	0.03	24.13
38			0.00		315.27	829.79	69.15	366.04	124.47	559.66	58.76	992.40	2196.23	2496.68	879.66	0.03	22.24
39			0.00		315.27	869.37	72.45	372.92	130.41	575.77	60.46	992.40	2237.50	2496.68	896.19	0.02	20.52
40			0.00		315.27	910.84	75.90	380.12	136.63	592.65	62.23	992.40	2280.74	2496.68	913.51	0.02	18.93
			4289.40	**3326.20**												**10.37**	**8144.67**
																(A)	(B)
														LEVELISED TARRIF (B/A)			**785.33**
																	7.85

Chapter - XV
Recommendations

15.1 Recommendations

The total capacity of renewable energy sources is expected to be about 20,301 MW, constituting about 65% of total capacity in Andhra Pradesh by the year 2028-29. Considering the large scale addition of installed capacity from renewable (which are of intermittent/seasonal in nature) sources like solar and wind, it is essential to implement a suitable energy storage system for absorbing the surplus energy during peak generation from above sources and utilize the same during peak energy requirement, especially evenings/nights.

It is to be noted that currently there is no technology/option available in India or Globally to facilitate such large scale energy/power storage other than Pumped Storage Hydro Projects. Further, the cost of energy storage in case of battery energy storage systems (BESS) in the current scenario have been found to be on the higher side (~ Rs 20/kWhr) and cannot be considered.

As explained earlier in the report, it is suggested to consider development of Kurukutti & Karrivalasa PSP's as a single cluster by adopting a common lower reservoir. Accordingly, studies have been carried out & an installed capacity of about 1200 MW is adopted for Kurukutti PSP. The feasibility & necessity of detailed studies required for further evaluation of Kurukutti PSP has been reviewed considering various parameters/factors and the details are tabulated below:

Table - 15.1: Evaluation of Kurukutti PSP

Sl. No.	Parameter	Results	Remarks
I	**Technical**		
1.	Accessibility	Good	Well connected & has access to major roads & railway network within a short distance.
2.	Inter-state/ International Issues	Good	None
3.	Geology	Good	Favourable geology
4.	Water Availability (Initial Filling)	Good	Total average annual water availability = 57 Mm^3 in Boduru Gedda river basin at project site, vis-à-vis requirement of 51 Mm^3 required for

Sl. No.	Parameter	Results	Remarks
			operation of PSP. Thus, filling time would be about 1 to 2 years.
5.	Water Availability (Operation)	Good	90% dependable yield at project site is 22 Mm^3 vis-à-vis annual water requirement of about 2.4 Mm^3 for operation of project.
6.	Capacity	1200 MW	Generation capacity of project is significant & worth further evaluation.
7.	Cycle Efficiency	76%	Higher than the present benchmark value of 75% for PSP's.
8.	L/H Ratio	6.2	Good
II	**Commercial**		
9.	Capital Cost	Good	Rs 4.0 Crores/MW cost is an investment worth for such a large capacity project.
10.	Levelized Tariff	Good	• Rs 3.81/kWhr (without pumping cost) • Rs 7.85/kWhr (including pumping cost of Rs 3/kWhr) is reasonable as against BESS option.
III	**Environmental**		
11.	Land Issues	433 Acres	Land requirement is reasonable for a project of such magnitude.
12.	R & R Issues	Moderate	Involves submergence of habitations at Rampadu, Tadivalasa, & Nerellivalasa under the lower reservoir, in addition to submergence of agricultural lands and forest area of about 50 Hectares (to be apportioned between Kurukutti and Karrivalasa PSP's).

Considering the above aspects, the proposed Kurukutti PSP is an investment worthy project and hence recommended to be considered for further studies and detailed evaluation.

PHOTOGRAPHS

Upper Dam Site (AREMI)

Lower Dam Site (AREMI)

Lower Dam Site

Powerhouse Area

Gauging Site across Boduru Gedda River at Dandigam

Surge Shaft & WCS Area

220 / 400 kV Maradam Sub-station

Gauging Station at Dandigam
(Before Cleaning / Clearance)

Site Clearance Works

Gauging Station (After Site Clearance)

Installation & Calibration of Gauging Equipment
(Nivuflow 750 transmitter with ultrasonic wedge sensor)

Solar Powered Equipment for Gauging Equipment

Addendum Note

on

Daily Cycle of Operation

1.0 General

A weekly cycle of operation has been adopted for Kurukutti pumped storage project to meet the daily peak demand for about 7 hours, in a week (except Sundays). Off-peak pumping hours are considered as 7 hours daily on week days, with balance pumping on Sundays. The reservoir storage required for its operation, associated cost estimates and economic evaluation for project based on weekly regulation has been addressed in the respective Chapters of feasibility report.

NREDCAP vide its email dated 12th July 2021 and 02nd August 2021 requested to study the likely impact on project parameters and financial outcome of the project considering daily cycle of operation. This addendum note briefly addresses the key aspects of the project considering daily cycle of regulation/operation.

2.0 Storage Requirement & Project Parameters

The maximum net / live storage required for operation of 1200 MW PSP has been estimated to be about 6.1 Mm^3 as against 11.0 Mm^3 required for weekly regulation. The project parameters have been estimated considering peak generation for about 7 hours and off-peak pumping for a duration of about 8.35 hours in a day for entre week. The resulting parameters of PSP are as given below:

a) Upper Reservoir
- Full Reservoir Level - RL 889.00 m
- Minimum Drawdown Level - RL 861.00 m

b) Lower Reservoir
- Full Reservoir Level - RL 299.00 m
- Minimum Drawdown Level - RL 281.00 m

c) Gross Head - 587 m

d) Rated Head
- Generation - 567 m
- Pumping - 601 m

e) Rated Discharge
- Generation - 48.4 m^3/s per unit
- Pumping - 40.6 m^3/s per unit

f) Generation hours in a week - 49 hours (7 hours for 7 days)

g) Pumping hours in a week - 58.3 hours (8.35 hours for 7 days)

h) Annual Energy
- Generation - 2948 GWh
- Pumping - 3860 GWh

3.0 Project Cost & Levelized Tariff

The capital cost of project has been estimated and found to be about Rs 4685 Crores. Break-up of cost is as given below:

a)	Civil & HM works	- Rs 1214 Crores
b)	Electro-mechanical works	- Rs 2400 Crores
c)	Power Evacuation works	- Rs 73 Crores
d)	Other costs	- Rs 469 Crores
	Total Cost (including FC)	**- Rs 4156 Crores**
e)	Interest During Construction	- Rs 529 Crores
f)	**Total Cost**	**- Rs 4685 Crores**

Levelized cost of generation

a) Rs 3.21/kWhr, with cost of pumping @ Rs 0.0/kWhr

b) Rs 7.25/kWhr, with cost of pumping @ Rs 3.0/kWhr

4.0 Concluding Remarks

Based on studies carried out, it is found that the levelized cost of generation is lower for PSP considering daily cycle of operation, which is mainly due to increased hours of operation. If duration of operation for weekly regulation is also assumed as 49 hours of generation in a week (i.e., same as Daily Cycle of operation), then levelized cost of generation is found to be comparable for both types of regulation.

However, it is prudent to note that proposed PSP is being planned as energy storage scheme for the large scale capacity additions from renewable energy sources (predominantly solar) being implemented in the State in order to balance variable renewable power. Availability of 8.35 hours of daily off-peak power throughout the year from Solar plants, especially during winter / monsoon months could be a major constraint if daily cycle of operation is adopted for the project.

Since, there is no provision for additional storage in the reservoirs, PSPs designed based on daily cycle of operation offers no flexibility and may result in sub-optimal utilization of plant capacity. Also, it is an established fact that the requirement of peak power is less on Sundays compared to weekdays. As such, designing plant to operate for the entire week may not be feasible considering reduced demand for peak power on Sundays.

On the other hand, PSPs designed on weekly cycle of operation offer higher flexibility by pumping the balance volume of water on Sunday when low cost off-peak power is available from State / National grid. Further, this will also provide additional advantages /operational flexibility such as:

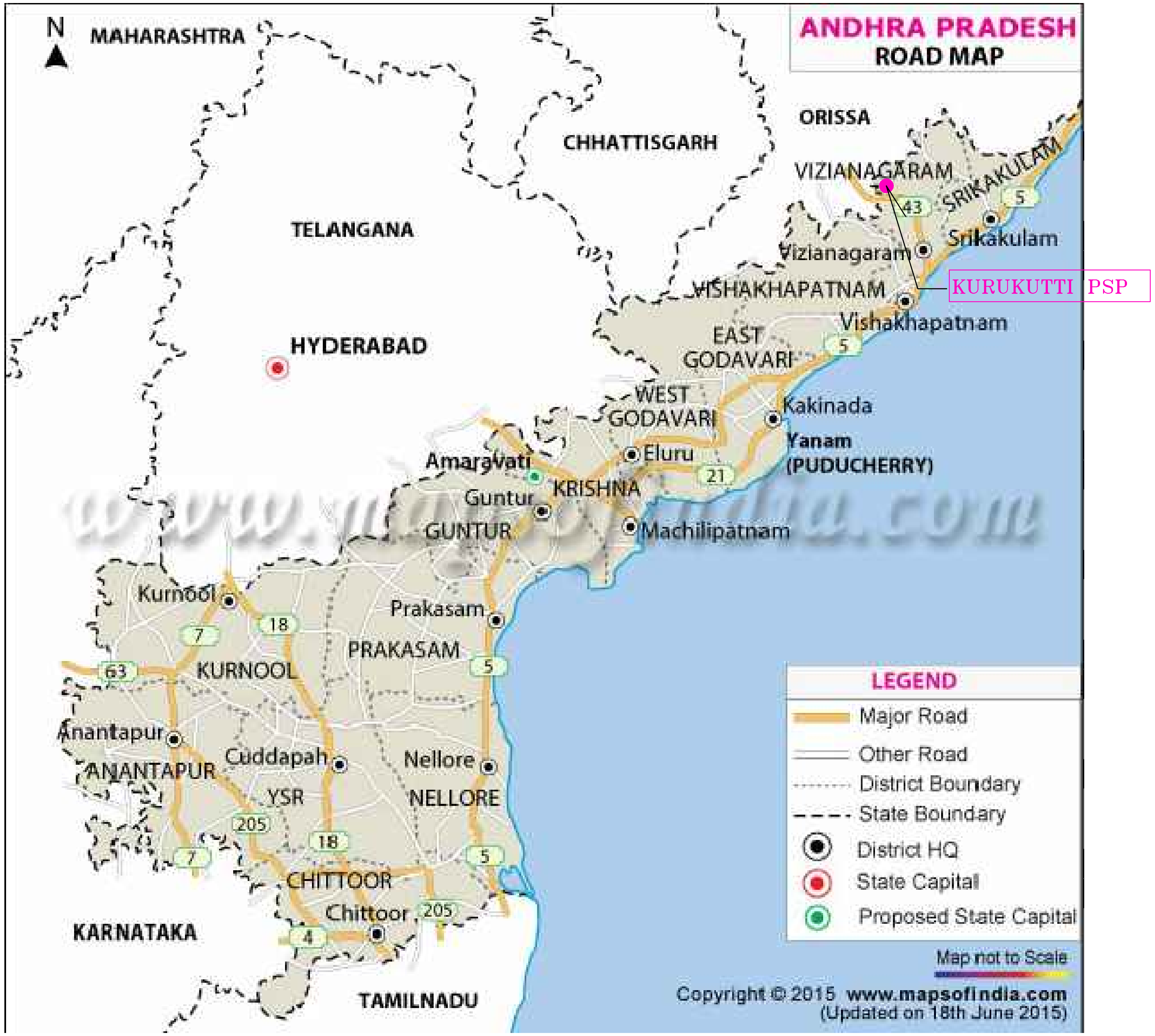
- Catering to daily variability of renewable power (Solar)
- Variations in winter and monsoon months

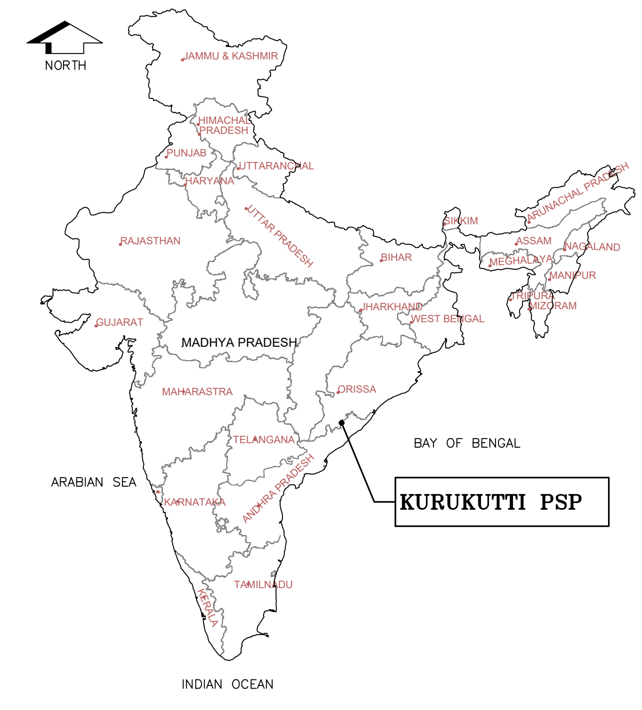
As seen from Table - 14.5, levelized cost of generation is highly sensitive to cost of pumping and hence, adoption of weekly cycle of operation gives the operator/developer more choice in utilizing low cost off-peak power available on Sundays to minimize the operational expenses of plant, which would be beneficial.

5.0 Further Studies

The type of regulation (Daily versus Weekly) required to be considered for proposed Kurukutti PSP will be studied in detail during preparation of DPR based on the outcome of supply-demand and other inter-related studies. The availability and duration of off-peak power required for pumping along with requirement for peaking generation on Sundays will also be reviewed considering State and National electricity grid data.

NORTH





KEY PLAN

REF MAP

1. STATE MAP OF INDIA – SOI
2. ROAD MAP OF ANDHRA PRADESH

FOR REPORT PURPOSE	EXHIBIT – 1

NEW AND RENEWABLE ENERGY DEVELOPMENT CORPORATION OF ANDHRA PRADESH LIMITED (NREDCAP)

KURUKUTTI PUMPED STORAGE PROJECT (5X240=1200MW)

INDEX PLAN

TATA CONSULTING ENGINEERS LIMITED
MUMBAI

SCALE	DRN	SKETCH No	DATE
NTS	Sunitha	TCE.12058A-CV-3074-SK-31101	AUG 2021